

Three Essays in Competition Economics

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von
M.Sc. Dongyu Guo

Präsident der Humboldt-Universität zu Berlin:
Prof. Dr. Jan-Hendrik Olbertz

Dekan der Wirtschaftswissenschaftlichen Fakultät:
Prof. Dr. Ulrich Kamecke

Gutachter:
1. Prof. Dr. Roland Strausz
2. Prof. Dr. Helmut Bester

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Introduction

As the title shows, this thesis is about competition economics. The thread of this thesis is the analysis of circumstances where unfettered competition does not drive efficient outcomes and there is potentially scope for public intervention. The following three chapters consider situations that require a decreasing degree of public intervention. The first chapter explores the antitrust scrutiny of mergers in markets that need regulatory supervision. The second chapter considers mergers in a competitive environment. The third chapter examines a situation where market frictions induce a distortion from the purely competitive outcome but do not justify any public intervention.

Chapter 1 is based on joint work with Raffaele Fiocco (Fiocco and Guo 2014). We investigate the optimal merger policy involving regulated firms. Recent decades have witnessed merger waves in industries in large part under regulatory control, such as electricity, gas, sanitation, telecommunications, transportation and water. We consider a merger between two regulated firms operating in two separate markets, and in each market a regulated firm interacts with unregulated competitors. Efficiency gains are uncertain before the merger and their realization becomes private information of the merged firms. In line with existing literature, the merger entails a trade-off between the benefits of potential efficiency gains from joint production and the costs of distortions in the regulatory policy. Under a consumer surplus standard, we show that, as a result of this trade-off, the optimal merger policy depends on the intensity of competition between unregulated firms. In particular, fiercer competition between unregulated firms induces a more lenient merger policy. This is because fiercer competition entails a more efficient response of unregulated firms to changes in their demand driven by distortions in the regulatory policy due to informational problems. These results can be reversed if

the regulated firms expand into a competitive segment of the market. In particular, when the regulated and unregulated goods are complements, the merged firm's internalization of competitive profits arising from weaker competition (such as Cournot instead of Bertrand competition) alleviates the regulator's incentive problem and relaxes the merger policy.

In Chapter 2, I study the optimal merger policy between two competitive firms. Since Williamson (1968), it is well-established in the economic literature that a welfare trade-off arises between market power and efficiency gains generated by a merger. In the recent 20 years, a structural remedy, which aims at creating the conditions for the emergence of a new competitive entity or for the strengthening of existing competitors via divestiture, has been treated as the most effective manner to restore effective competition. Among the structural remedies, there is one relevant type, namely, the divestiture of differentiated brands to other competitor(s). I focus on this particular remedy in a Cournot oligopolistic market and show that it is a powerful tool to lessen the merged entity's market power. Divestiture can increase the scope for privately and socially desirable mergers. In particular, I show that when goods are closer to perfect substitutability, then the merging firms are more inclined to give some brands to competitor(s), because the markup on each brand is lower. Therefore the range of the efficiency gains which allows the merger with remedies to be approved is larger.

Chapter 3 is based on joint work with Fabio Antoniou and Raffaele Fiocco (Antoniou, Fiocco and Guo 2015). We investigate the well-established observation that retail prices adjust faster when input costs rise than when they fall. This phenomenon, also known as “rockets and feathers” is common in many industries, such as gasoline, coffee, corn and banking. Differently from the existing literature, which has focused either on the consumer side or on collusion, we provide an explanation from the supply side to asymmetric price adjustments, using a model of two-period dynamic price competition. We show that the presence of profitable storing allows competitive firms to credibly commit to immediately increase their prices above current marginal costs when they anticipate higher input costs. This relaxes competition and firms earn positive profits. If input costs are expected to decline, the firms are trapped in the Bertrand paradox and price adjustment is slower. Storing drives asymmetric pricing even under alternative markets struc-

tures, such as monopoly or Cournot competition.

Chapter 1

Mergers between regulated firms with unknown efficiency gains

This chapter is based on Fiocco and Guo (2014).

1.1 Introduction

The adequate antitrust scrutiny of mergers between firms is a relevant policy issue in modern countries. The US Horizontal Merger Guidelines (HMG), revised by the Department of Justice and the Federal Trade Commission in 2010, and the EC Merger Regulation reformed in 2004 have acknowledged the relevance of cost synergies in merger control. Two major practical problems recognized by antitrust authorities and courts concern the uncertainty about the magnitude of efficiency gains before the merger and the merging firms' privileged information about the realization of efficiency gains. Antitrust authorities emphasize the issue of uncertainty, since "efficiencies projected reasonably and in good faith by the merging firms may not be realized" (HMG, Sect. 4).¹ Moreover, as declared by Judge T. F. Hogan for the 1997 merger case of Staples and Office Depot, "the Court agrees with the defendants that where, as here, the merger has not yet been consummated, it is impossible to quantify precisely the efficiencies that it is will

¹Document available at <http://www.justice.gov/atr/public/guidelines/hmg-2010.html>.

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generate” (US District Court for the District of Columbia, Civ. No. 97-701).²

After the merger materializes, the merged firm can privately learn the realization of efficiency gains. In fact, “efficiencies are difficult to verify and quantify, in part because much of the information relating to efficiencies is uniquely in the possession of the merging firms” (HMG, Sect. 4). As Amir et al. (2009, p. 266) point out, “this *first-to-know advantage* thus emerges as a natural candidate for the fundamental asymmetry that mergers seem to trigger in favor of the merged firm”.

The aim of this chapter is to investigate the welfare effects of a merger between regulated firms when efficiency gains from joint production are uncertain before the merger and their realization becomes private information of the merged entity.

Despite the importance of this phenomenon, mergers in regulated industries have received so far little theoretical attention. Recent decades have witnessed merger waves in industries in large part under regulatory control, such as electricity, gas, sanitation, telecommunications, transportation and water. Since enterprises with large numbers of customers and considerable assets are usually involved, the economic relevance of the consolidation process in regulated industries is definitively high. The 2014 report of Ernst & Young on worldwide mergers and acquisitions of regulated utilities underlines that “strong momentum behind merger and acquisition (M&A) activity in the global power and utilities (P&U) sector continued, driving deal value to US\$38.6b — the highest third-quarter deal value since Q3 2010”. The empirical literature has investigated the impact of mergers in utility sectors on operating costs and shareholder wealth creation (e.g., see Kwoka and Pollitt (2010) and Datta et al. (2013) and the references cited therein).

Notable examples of mergers in regulated industries abound. E.ON, one of the world’s largest energy utility providers, was created in 2000 as a result of the merger between Veba (traditionally established in northern Germany) and Viag (traditionally established in southern Germany), with a deal value of about 14 billion dollars. In 2012 Duke Energy, operating in Indiana, Kentucky, Ohio

²This conclusion is also supported by empirical evidence and stylized facts. Motta (2004, Ch. 5, p. 242) states that “merging parties often have a genuine tendency to overstate the benefits from combining their activities and assets. Even strictly internal and confidential documents often report too optimistic an assessment of the merger’s efficiency gains”.

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and Western Carolinas, merged with Progress Energy, operating in Florida and Eastern Carolinas. This merger was realized through a transaction of about 32 billion dollars and generated the largest energy utility in the US by number of customers. On November 20, 2014 the US Federal Energy Regulatory Commission (FERC) approved the merger between Exelon, which distributes electricity to approximately 6.6 million customers in Illinois, Pennsylvania and Maryland, and Pepco, which serves the District of Columbia and the surrounding communities.³ The Regional Bell Operating Companies (RBOCs), which provide regulated local telephone services in distinct areas of the US as a result of the 1984 divestiture of AT&T, have engaged after the enactment of the Telecommunications Act of 1996 in merger operations that have reduced their number from seven to only three.⁴

The consolidation process in regulated industries is also pervasive outside the US. The number of electric utilities in Ontario fell from over 300 in the 1990s to 74 in 2011 as a result of merger activities (Kushner and Ogwang 2014). According to the latest available (2007) report of the European Commission on mergers and acquisitions, 1002 mergers occurred in 2006 in European regulated network industries, which represent 11.6% of all merger deals. Mergers between regulated utilities seem to be particularly popular in Italy. A2A S.p.A., the third largest Italian electricity company, was created in 2008 from the merger between AEM Milan and ASM Brescia, operating in two different areas of Lombardy. In 2012 Hera, the third largest Italian gas company based in Bologna, merged with AcegasAps Group, which serves Padua and Trieste.⁵

The empirical evidence and the stylized facts discussed so far indicate that a natural feature of mergers in regulated industries is that they involve firms operating in distinct territories. Kwoka and Pollitt (2010) emphasize this aspect in their analysis of the consolidation process in the US electricity sector, where more than 75 mergers occurred between 1994 and 2003, involving half of the customers of all investor-owned electricity companies, with a total deal value of over 300 billion dollars. To illustrate the nature of this consolidation process, Kwoka and

³Details on the most significant mergers between regulated utilities filed by the FERC can be found at <http://www.ferc.gov/industries/electric/gen-info/mergers.asp>.

⁴Cox and Portes (1998) provide some relevant case studies of mergers in regulated industries.

⁵We refer to Grossi et al. (2010) for a discussion of the institutional trends in local public utilities in Europe.

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Pollitt (2010, p. 647) refer to the merger realized in 1999 between Boston Edison, the major utility serving Boston, and Commonwealth Energy System, which operates in neighboring Cambridge (through its subsidiary Cambridge Electric) and in southern Massachusetts.

Over the last decades most regulated industries have been involved in a partial liberalization process that has increased the scope for demand interconnections between regulated and unregulated firms. In the energy sector, transmission and distribution networks are typically regulated, while retail services are often open to competition. Regulated local telephone services coexist with unregulated telecommunications services, such as broadband Internet, long-distance and digital cable telephone services. Regulated railways operate in competition with unregulated long-distance buses and airlines. In big cities, regulated public utilities run railways, subways and buses, while unregulated firms supply alternative services such as car sharing or car rental. As Aubert and Pouyet (2006) emphasize, a major characteristic of current regulatory structures is that regulated and unregulated firms interact by providing differentiated products.

In this chapter we characterize the optimal merger policy involving regulated firms, whose task is to find a balance between the benefits of potential efficiency gains from the merger and the costs of distortions in the regulatory policy due to the aforementioned informational problems about efficiency gains. We explore this trade-off in a setting where a merger occurs between two regulated firms operating in two separate markets. The previous discussion indicates that mergers in regulated industries typically involve firms that provide the same service but operate in different regions, since they constitute local natural monopolies. This is the case of energy networks, local telephone services and local public transportation.

In each market a regulated firm interacts with unregulated competitors because they provide goods that exhibit either some degree of substitutability (e.g., regulated railways and unregulated buses) or complementarity (e.g., regulated energy networks and unregulated retail services). Our purpose is to investigate the impact of the intensity of competition in the unregulated part of the market on the optimal merger policy involving regulated firms. For the sake of concreteness, we consider two standard modes of competition. Unregulated firms compete either fiercely in Bertrand fashion (as in a classical competitive fringe model), which entails zero

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market power, or in Cournot fashion, which is less intense and leads to higher profits. The main difference between these two modes of competition lies in the degree of toughness of product market competition or “toughness of price competition” (Sutton 1991).⁶ Since competition is typically tougher (namely, the firms’ market power and associated profits decline) as the number of firms increases, our qualitative results carry over if we consider the impact of the number of firms in the unregulated part of the market on the optimal merger policy in any standard setting of (imperfect) competition.

We find that, in the presence of uncertainty over post-merger costs before the merger occurs, Bertrand competition leads to a more lenient merger challenge rule than Cournot competition. To understand the rationale for this result, it is important to realize that, when post-merger costs are uncertain, an *ex ante* welfare-enhancing merger may eventually result in higher costs, namely, efficiency losses, driven for instance by clashes between corporate cultures (e.g., White 1987).⁷ In this case, even when post-merger costs become common knowledge, the regulated production decreases because regulated activities are more inefficient. As Bertrand competition is more intense than Cournot competition, Bertrand competitors react more aggressively to changes in their demand stemming from regulated output reductions. Hence, more intense competition relaxes the condition for allowing the merger. Private information of the merged firm about the realization of post-merger cost synergies strengthens this result. As it is well established in the optimal regulation literature (e.g., Baron and Myerson 1982), a regulator prefers to tolerate some allocative inefficiency from the downward output distortion for the inefficient firm in order to limit the (socially costly) informational rents appropriated by the efficient firm. The more prompt reaction of Bertrand competitors to reductions in the regulated output with respect to Cournot competitors alleviates the allocative costs of downward regulated output distortions and softens the

⁶It is fairly common in the literature on industrial organization and regulation to compare Bertrand and Cournot competition when investigating the welfare effects of the nature of competition in different industry structures. We refer to Calzolari and Scarpa (2014) for such a comparison in a model where, as in our setting, efficiency gains generated by a merger are private information of the merging firms. Mandy and Sappington (2007) and Chen and Sappington (2010) are further prominent examples of investigations based on the comparison between Bertrand and Cournot competition. In Section 1.3 we provide additional discussion on this point.

⁷In Section 1.3 we discuss the possibility of efficiency losses.

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regulator's incentive problem.

In the second part of the chapter, we show that these predictable results can be reversed if regulated firms diversify into a competitive segment of the market. In the energy, telecommunications and transportation sectors, regulated utilities often have affiliates in the liberalized part of the market where they operate. While the intensity of Bertrand competition tends to erode the firms' profits and therefore makes the regulated firms' diversification into the unregulated segment inconsequential, things are different under Cournot competition. In particular, when the regulated and unregulated goods are complements, competitive profits can discipline the diversified merged firm's strategic behavior. The efficient merged firm has a weaker incentive to claim to be inefficient since a lower regulated quantity due to cost misrepresentation reduces the demand and the profits in the unregulated segment. The regulated firm's internalization of competitive profits alleviates the regulator's incentive problem and relaxes merger policy. In this case, the regulated firm's diversification into a competitive segment implies that softer competition leads to a more lenient merger challenge rule.

To the best of our knowledge, this chapter constitutes the first attempt to shed some light on the welfare effects of informational problems about efficiency gains due to mergers between regulated firms. Our analysis recommends a serious assessment of the intensity of competition in markets where merging regulated firms interact with unregulated competitors. It also provides theoretical support for the view of practitioners and policy makers that the effects of mergers between regulated firms on regulatory policies deserve adequate investigation. For instance, as emphasized in the Order issued on February 16, 2012, the Federal Energy Regulatory Commission (FERC) considers the impact on rates and regulation as a crucial factor when evaluating a proposed merger between regulated utilities.⁸ Despite the stylized formulation for expositional purposes, the principles underlying our results are fairly general. Our analysis may therefore stimulate the theoretical and practical debate on antitrust and regulatory policies.

⁸Document available at <http://ferc.gov/whats-new/comm-meet/2012/021612/E-2.pdf>.

1.2 Related literature

The emphasis on efficiency gains in merger reviews in unregulated markets traces back to the seminal paper of Williamson (1968) that investigates the welfare trade-off between market power and efficiency gains generated by a merger. Our work is related to two main strands of the merger literature. The first strand explores the role of pre-merger uncertainty and post-merger private information about efficiency gains. Choné and Linnemer (2008) examine the welfare effects of uncertainty according to the curvature of the social objective function but ignore the presence of asymmetric information after the merger. Closer to our work is the paper of Amir et al. (2009) that analyzes the merger performance when efficiency gains are uncertain before the merger and the merging firms privately observe their realization after the merger. The authors show that a bilateral merger is profitable if non-merging firms believe with a sufficiently high probability that the merger will engender large efficiency gains, even though none actually realize. Along these lines, Hamada (2012) demonstrates that, as the variance of uncertainty about synergies grows, mergers generate larger expected profits and improve expected consumer surplus. Calzolari and Scarpa (2014) explore the welfare effects of allowing a firm established in regulated and competitive markets to combine its assets, which creates privately known economies of scope. Contrary to these works, we examine mergers between regulated firms.

The second strand of literature that is relevant for our purposes investigates the optimal institutional design of regulated industries. We refer to Armstrong and Sappington (2007) for a review on optimal regulation. In a setting with complementary products and private cost information, Baron and Besanko (1992) and Gilbert and Riordan (1995) show that allowing a single firm to integrate production improves social welfare through a reduction in informational rents. Iossa (1999) finds that (dis)integrated production tends to be preferred with substitutes (complements) when asymmetric information concerns consumer demand. Contrary to these contributions which ignore technological economies of scope and assume that markets are entirely regulated, we explore the role of uncertainty and asymmetric information about efficiency gains in an industry where regulated and unregulated firms interact.

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The rest of the chapter is organized as follows. Section 1.3 sets out the formal model. Section 1.4 considers the benchmark case of full information. Section 1.5 characterizes the optimal merger policy under uncertainty and asymmetric information about post-merger costs. Section 1.6 derives the optimal merger policy when regulated firms diversify into a competitive segment of the market. Section 1.7 discusses some assumptions of the model. Section 1.8 concludes and provides some policy implications. All formal proofs are collected in the Appendix.

1.3 The model

Setting We wish to investigate the welfare implications of a merger between two regulated firms that operate in two separate markets, for instance two different regions of a country. In each market a regulated firm interacts with unregulated competitors since they provide differentiated goods.

Following Aubert and Pouyet (2006), gross consumer surplus in each market $i = 1, 2$ is specified by a utility function à la Singh and Vives (1984) of the form

$$U_i = \alpha q_{ir} + \alpha q_{iu} - \frac{1}{2}(q_{ir}^2 + q_{iu}^2 + 2\gamma q_{ir}q_{iu}), \quad (1.1)$$

where q_{ir} and q_{iu} respectively denote the quantity of the regulated good and the quantity of the unregulated good in market i . Consumer surplus in (1.1) yields a system of linear inverse demand functions in market i given by

$$\begin{aligned} p_{ir} &= \alpha - q_{ir} - \gamma q_{iu} \\ p_{iu} &= \alpha - q_{iu} - \gamma q_{ir}, \end{aligned}$$

where $\alpha > 0$ is the demand intercept and $\gamma \in (-1, 1)$ captures the degree of product differentiation between the regulated good and the unregulated good.⁹ If $\gamma > (<)0$, goods are substitutes (complements). As discussed in Section 1.1, regulated railways and unregulated buses exhibit some degree of substitutability, as well as regulated local telephone and unregulated Internet services. In the energy sector, regulated networks and unregulated retail services are classical examples

⁹Without loss of generality, the slope of the demand function is normalized to 1. The standard assumption $|\gamma| < 1$ guarantees that own-price effects are larger than cross-price effects.

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of complementary goods. To make our analysis more transparent, and without affecting our qualitative results, we assume that the two markets are symmetric. This reflects the idea that mergers in regulated industries usually involve local natural monopolies which provide the same service (e.g., energy, telecommunications, transportation) but operate in different regions and face a similar competitive segment in each region.¹⁰

In the absence of a merger, one regulated firm is established in each market. The profit of regulated firm $i = 1, 2$ is

$$\pi_{ir} = T_{ir} - cq_{ir}, \quad (1.2)$$

where T_{ir} is a transfer payment to the firm via the regulatory process and c is the (constant) marginal cost of production.¹¹ As discussed further below, a regulatory contract specifies a quantity to be produced and a transfer to the firm, while no price is charged for the regulated good. Therefore, our analysis identifies a classical procurement problem, where the regulated firm receives a transfer for the quantity produced. As it is well established in the optimal regulation literature, the regulatory outcome associated with this transfer can be replicated with a two-part tariff that consists of a unit price and a fixed fee.

If the two regulated firms merge, a single regulated entity operates in the two markets. The profit of the merged regulated firm is

$$\pi_r = T_r - C(q_{1r}, q_{2r}; \theta), \quad (1.3)$$

where T_r is a transfer payment to the firm and $C(q_{1r}, q_{2r}; \theta) = cq_{1r} + cq_{2r} - \theta q_{1r}q_{2r}$ represents the total cost of production after the merger. This cost function captures in a simple and natural manner the presence of interdependent costs.¹² If $\theta = -\frac{\partial^2 C}{\partial q_{ir}\partial q_{jr}} > (<)0$, $i, j = 1, 2$, $i \neq j$, joint production generates efficiency gains (losses), or (dis)economies of scope, since a larger output of one product reduces (increases) the marginal cost of the other product.

¹⁰In line with the main literature, we abstract from an analysis of the optimal degree of (de)regulation.

¹¹Nothing substantial would change with non-linear, different marginal costs.

¹²See, e.g., Motta (2004, Ch. 8) and Calzolari and Scarpa (2009, 2014) for the use of this cost specification.

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Following Farrell and Shapiro (2001, pp. 692-693), efficiency gains are interpreted as merger-specific synergies obtained through the “intimate integration of the parties’ unique, hard-to-trade assets”.¹³ Before the merger, the magnitude of cost synergies is uncertain. It is common knowledge that with probability $\nu \in (0, 1)$ the merger entails efficiency gains $\theta_h > 0$. In line with the main literature about uncertain efficiency gains (e.g., Amir et al. 2009), this probability can be thought of as the common belief about the merged firm’s ability to achieve the posited efficiency gains, given the information available about the case and possibly all previously treated similar cases. After the merger, the merged firm privately learns the realization of cost synergies. With complementary probability $1 - \nu$, the merger results in efficiency losses $\theta_l < 0$, where $\Delta\theta \equiv \theta_h - \theta_l > 0$. Integrating production may entail higher costs caused, for instance, by clashes between corporate cultures and difficulties in melding two different managerial and production systems. In the largest cross-national study on mergers over the period 1981-1998, Gugler et al. (2003) conclude that only 29% of all mergers created efficiency gains. In regulated industries such as electricity, railways and water, empirical investigations show that mergers may entail efficiency losses (e.g., Bitzan and Wilson 2007; Kwoka and Pollitt 2010; Torres and Morrison Paul 2006). In the theoretical literature, efficiency losses after a merger are explicitly modelled in some recent contributions (e.g., Choné and Linnemer 2008; Hamada 2012).

Cost synergies constitute the unique parameter of private information in our model. This allows us to focus on the informational effects of the merger and makes our analysis more transparent. Remarkably, this formulation is consistent with the common idea that a regulator can (at least to some extent) extract the private information of monopolists established in different regions by implementing yardstick competition. After the merger, this becomes clearly more difficult and the new entity is in a better position to manipulate its costs. Further discussion in support of our framework is provided in Section 1.7.1.

In the unregulated segment of each market, two firms $s = 1, 2$ provide a homogeneous good and obtain profits $\pi^{is} = p_{is}q_{is} - cq_{is}$, where p_{is} is the price for the

¹³We ignore savings on fixed costs which follow from a reduction in administrative and personnel costs after the merger, since they do not affect our qualitative results. These synergies are viewed with skepticism by antitrust authorities, because they typically stem from a mere output reorganization that could be achieved without the merger (e.g., Motta 2004, Ch. 5).

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good provided by firm s in market i ($p_{is} = p_{iu}$ in equilibrium) and q_{is} is the corresponding output, with $\sum_{s=1}^2 q_{is} \equiv q_{iu}$.¹⁴ Since efficiency gains from the merger must be merger-specific, they do not affect the costs in the competitive segment. The unregulated firms engage either in Bertrand (price) competition or in Cournot (quantity) competition. As discussed in the introduction, the difference between these two standard modes of competition captures in a simple and tractable manner the intensity or toughness of product market competition.¹⁵ Specifically, the equilibrium of a two-stage game where firms choose capacities and then prices coincides with the Cournot equilibrium, in which quantities are to be interpreted as capacities (Davidson and Deneckere 1983). Cournot competition is less intense than Bertrand competition and typically characterizes those markets where firms have the opportunity to choose investment levels (capacities) that soften price competition (Tirole 1988, Ch. 5).

Using (1.1), the aggregate net consumer surplus in the two markets is given by

$$CS = U_1 + U_2 - (T_{1r} + T_{2r}) - \sum_{s=1}^2 p_{1s}q_{1s} - \sum_{s=1}^2 p_{2s}q_{2s}, \quad (1.4)$$

with $T_{1r} + T_{2r}$ being replaced by T_r in case of merger. A regulator is charged with maximizing welfare in (1.4) when designing the regulatory policy.¹⁶ In the absence of the merger, the regulator offers a contract T_{ir}, q_{ir} to regulated firm $i = 1, 2$. If the merger occurs, the contract offered to the merged regulated entity is T_r, q_{1r}, q_{2r} . It is worth noting that the regulatory contract specifies a pair of transfer and quantity for each good, irrespective of the mode of competition in the unregulated segment. Using standard techniques, our results carry over if we consider the regulation of prices instead of quantities.

The welfare standard in (1.4) is also relevant to merger policy. This reflects the

¹⁴Our qualitative results carry over with product differentiation (and possibly different costs) even within the competitive segment of each market. Our analysis can also be generalized to the case of more than two firms.

¹⁵In Section 1.8 we provide practical examples where Bertrand or Cournot competition may tend to prevail.

¹⁶Without loss of generality, we neglect the social cost of collecting funds through distortionary taxation to finance regulated production (e.g., Laffont and Tirole 1986). This increases unnecessarily further the cost of transfers in the welfare function and does not affect our qualitative conclusions (Armstrong and Sappington 2007). In the same vein, our qualitative results go through if we allow for a weight (smaller than 1) attached to profits in the welfare standard in (1.4).

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common perception that, at least in Europe and in the US, antitrust authorities focus on consumer surplus in merger investigations (e.g., Motta 2004, Ch. 1).¹⁷

Timing The sequence of events unfolds as follows.

- (I) The regulator decides whether to allow the merger between the regulated firms or not.
- (II) If the merger is not allowed, the regulator makes a take-it-or-leave-it offer of a regulatory policy to each regulated firm, which can either accept or reject the offer (the reservation utility is normalized to zero). If merger is allowed, the merger takes place and the merged entity privately learns the realization of its cost type $\theta \in \{\theta_h, \theta_l\}$. Afterwards, the regulator makes a take-it-or-leave-it offer of a regulatory policy to the merged entity, which can either accept or reject the offer.
- (III) If the regulatory offer(s) is (are) accepted, regulation is implemented.
- (IV) Competition in the unregulated segment takes place.

In summary, after deciding on the merger, the regulator determines the regulatory policy and then competition occurs. We solve this game by backward induction.

Some remarks are in order at this point. We do not distinguish between the antitrust authority and the regulatory agency, since in practice they usually have concurrent jurisdiction over merger reviews in regulated industries and cooperate in reaching a final decision.¹⁸ Moreover, we consider a single regulator charged with controlling both markets. However, different regulators (one for each market) are sometimes established, and miscoordination problems might occur after the merger. While in our setting no externality arises on the demand side since consumers are located in different regions, the cost function in (1.3) of the merged firm is not separable in the two regulated outputs, and therefore assigning each regulator the control of a part of the merged firm's profits cannot be done unambiguously. To cope with regulatory miscoordination problems, in practice a regulator with a large jurisdiction is usually involved, such as the Federal Energy Regulatory Commission (FERC) for mergers and acquisitions of energy utilities

¹⁷Theoretical foundations can be found in Neven and Röller (2005).

¹⁸Miscoordination between the antitrust authority and the regulator would introduce additional issues that are outside the scope of our analysis.

1.4. FULL INFORMATION

in the US. Alternatively, active cooperation is promoted between different regulators. Since we aim at investigating the welfare effects of informational problems associated with efficiency gains, we abstract from additional issues arising from potential miscoordination between regulators.

In line with some relevant contributions to the merger literature (e.g., Amir et al. 2009; Calzolari and Scarpa 2014; Choné and Linnemer 2008; Hamada 2012), cost synergies are unknown before the merger. Their realization occurs after the merger and is privately observed by the merged firm. As argued in the introduction, practitioners acknowledge that cost synergies cannot be precisely quantified before a merger has been consummated, while the merged firm can have privileged information about their realization after the merger. Section 1.7.1 considers the case where the merging firms are better informed than the regulator even before the merger.

As in standard regulatory models, the implementation of regulatory contracting precedes the competition stage. This reflects the complexity of regulatory procedures that are more difficult to alter than market decisions.

Finally, we take as exogenously given the merger decision of the regulated firms. Section 1.7.2 is devoted to a discussion of the firms' incentives to merge.

1.4 Full information

For illustrative purposes, we present the benchmark case in which the magnitude of efficiency gains (losses) $\theta \in \{\theta_h, \theta_l\}$ is common knowledge before the merger takes place.

Remark 1 *With full information about $\theta \in \{\theta_h, \theta_l\}$, the merger is welfare enhancing if and only if $\theta = \theta_h$, irrespective of the mode of competition in the unregulated segment.*

In the absence of informational problems about post-merger costs, the merger desirability only depends on the magnitude of these costs. A merger should be approved if and only if it engenders efficiency gains, and competition in the unregulated segment is inconsequential.

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1.5 Unknown efficiencies

In the sequel, we show that the natural result in Remark 1 does not hold when post-merger costs are uncertain before the merger and their realization becomes private information of the merged firm.

1.5.1 Uncertainty

In order to better appreciate the impact of uncertainty and asymmetric information, we first consider the case in which cost synergies are uncertain before the merger and become common knowledge after the merger.

The following lemma formalizes the optimal merger policy with uncertain efficiency gains.

Lemma 1 *Suppose that $\theta \in \{\theta_h, \theta_l\}$ is uncertain before the merger and becomes common knowledge after the merger. Then, under Bertrand competition in the unregulated segment, the merger is ex ante welfare enhancing if and only if*

$$\nu > -\frac{1 - \gamma^2 - \theta_h}{(1 - \gamma^2)\Delta\theta}\theta_l \equiv \nu^b \in (0, 1). \quad (1.5)$$

Under Cournot competition in the unregulated segment, the merger is ex ante welfare enhancing if and only if

$$\nu > -\frac{9 - 4\gamma^2 - 9\theta_h}{(9 - 4\gamma^2)\Delta\theta}\theta_l \equiv \nu^c \in (0, 1). \quad (1.6)$$

We have $\nu^c \geq \nu^b$, where the equality holds if and only if $\gamma = 0$.

Lemma 1 reveals the predictable result that, when the magnitude of costs generated by the merger is uncertain, the merger should be approved only if the probability of efficiency gains is relatively high.¹⁹ More interestingly, conditions (1.5) and (1.6) show that in the presence of uncertainty the intensity of competition prevailing in the unregulated segment of the market affects the optimal merger policy. In particular, as the last part of Lemma 1 indicates, Bertrand competition

¹⁹The positivity conditions on quantities ensure $\nu^b \in (0, 1)$ and $\nu^c \in (0, 1)$. We refer to the proof of Lemma 1 (provided in the Appendix) for technical details.

1.5. UNKNOWN EFFICIENCIES

relaxes the condition for allowing the merger. Since the regulator's merger decision is made under uncertainty about cost realization, an ex ante welfare-enhancing merger may eventually result in efficiency losses, namely, higher post-merger costs, which lead to lower regulated production. Bertrand competition is more intense than Cournot competition, and therefore Bertrand rivals react more aggressively to reductions in regulated production. This alleviates the welfare losses from more inefficient post-merger regulated activities. As a result, more intense competition in the unregulated segment of the market allows the regulator to establish a merger challenge rule which is more lenient with the merging firms.

1.5.2 Uncertainty and asymmetric information

We now consider the case where cost synergies are uncertain before the merger and privately observed by the merged firm after the merger. Invoking the revelation principle (e.g., Myerson 1979), the regulator can restrict attention to a direct incentive compatible contract menu $\{(T_{rh}, q_{1rh}, q_{2rh}), (T_{rl}, q_{1rl}, q_{2rl})\}$ that induces the merged firm to truthfully reveal its cost type $\theta \in \{\theta_h, \theta_l\}$. Using the merged firm's profit in (1.3), the following incentive compatibility constraints must be fulfilled

$$\begin{aligned}\pi_{rh} &= T_{rh} - cq_{1rh} - cq_{2rh} + \theta_h q_{1rh} q_{2rh} \\ &\geq T_{rl} - cq_{1rl} - cq_{2rl} + \theta_h q_{1rl} q_{2rl} \\ &= \pi_{rl} + \Delta\theta q_{1rl} q_{2rl},\end{aligned}\tag{1.7}$$

$$\begin{aligned}\pi_{rl} &= T_{rl} - cq_{1rl} - cq_{2rl} + \theta_l q_{1rl} q_{2rl} \\ &\geq T_{rh} - cq_{1rh} - cq_{2rh} + \theta_l q_{1rh} q_{2rh} \\ &= \pi_{rh} - \Delta\theta q_{1rh} q_{2rh}.\end{aligned}\tag{1.8}$$

Conditions (1.7) and (1.8) ensure that the merged firm does not benefit from misreporting its private information. Adopting standard techniques, we find that the incentive condition (1.7) for the efficient firm is binding at the optimal contract.²⁰

²⁰See the proof of Lemma 2 (provided in the Appendix) for technical details.

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After defining

$$\phi(\nu) \equiv \frac{\nu}{1-\nu}, \quad (1.9)$$

we are in a position to characterize the optimal regulatory policy when the merger is permitted.

Lemma 2 *Suppose that $\theta \in \{\theta_h, \theta_l\}$ is uncertain before the merger and becomes private information of the merged firm after the merger. If the merger is allowed, under Bertrand competition in the unregulated segment, the outputs in market i are*

$$\begin{aligned} \tilde{q}_{irh}^{mb} &= \frac{(1-\gamma)(\alpha-c)}{1-\gamma^2-\theta_h}, & \tilde{q}_{irl}^{mb} &= \frac{(1-\gamma)(\alpha-c)}{1-\gamma^2-\theta_l+\Delta\theta\phi}; \\ \tilde{q}_{iuh}^{mb} &= \frac{(1-\gamma-\theta_h)(\alpha-c)}{1-\gamma^2-\theta_h}, & \tilde{q}_{iul}^{mb} &= \frac{(1-\gamma-\theta_l+\Delta\theta\phi)(\alpha-c)}{1-\gamma^2-\theta_l+\Delta\theta\phi}. \end{aligned}$$

Under Cournot competition in the unregulated segment, the outputs in market i are

$$\begin{aligned} \tilde{q}_{irh}^{mc} &= \frac{(9-4\gamma)(\alpha-c)}{9-4\gamma^2-9\theta_h}, & \tilde{q}_{irl}^{mc} &= \frac{(9-4\gamma)(\alpha-c)}{9-4\gamma^2-9\theta_l+9\Delta\theta\phi}; \\ \tilde{q}_{iuh}^{mc} &= \frac{6(1-\gamma-\theta_h)(\alpha-c)}{9-4\gamma^2-9\theta_h}, & \tilde{q}_{iul}^{mc} &= \frac{6(1-\gamma-\theta_l+\Delta\theta\phi)(\alpha-c)}{9-4\gamma^2-9\theta_l+9\Delta\theta\phi}. \end{aligned}$$

Lemma 2 reveals the familiar trade-off between allocative efficiency and the firm's rent extraction in the presence of asymmetric information (e.g., Baron and Myerson 1982). The production of the efficient firm coincides with that under symmetric information ("no distortion at the top" result). However, the regulator finds it optimal to reduce the output of the inefficient firm in order to limit the (socially costly) informational rents in (1.7) appropriated by the efficient firm. The quantities for the two goods of the inefficient merged firm are distorted downwards, since asymmetric information concerns the costs of joint production.

Equipped with the results in Lemma 2, we can characterize the optimal merger policy in the presence of uncertainty and asymmetric information.

Proposition 1 *Suppose that $\theta \in \{\theta_h, \theta_l\}$ is uncertain before the merger and becomes private information of the merged firm after the merger. Then, under Bertrand competition in the unregulated segment, the merger is ex ante welfare*

1.5. UNKNOWN EFFICIENCIES

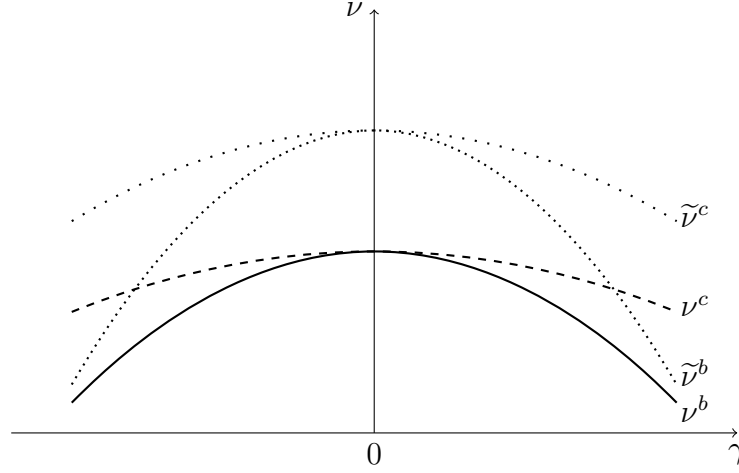


Figure 1.1: Merger policy

enhancing if and only if

$$\nu > -\frac{1 - \gamma^2 - \theta_h}{\theta_h^2 - (1 - \gamma^2)\theta_l} \theta_l \equiv \tilde{\nu}^b \in (\nu^b, 1). \quad (1.10)$$

Under Cournot competition in the unregulated segment, the merger is ex ante welfare enhancing if and only if

$$\nu > -\frac{9 - 4\gamma^2 - 9\theta_h}{9\theta_h^2 - (9 - 4\gamma^2)\theta_l} \theta_l \equiv \tilde{\nu}^c \in (\nu^c, 1). \quad (1.11)$$

We have $\tilde{\nu}^c - \tilde{\nu}^b \geq \nu^c - \nu^b \geq 0$, where the equality holds if and only if $\gamma = 0$.

When cost synergies are uncertain before the merger and their realization becomes private information of the merged firm, the merger yields a trade-off between the benefits of potential efficiency gains and the social costs of regulatory distortions. The combination of pre-merger uncertainty and post-merger asymmetric information complicates the regulator's informational problem. Hence, irrespective of the mode of competition, the regulator selects a merger challenge rule that is more severe than in the case of only pre-merger uncertainty.²¹

Figure 1.1 illustrates the results in Lemma 1 and Proposition 1. As the last part of Proposition 1 reveals, asymmetric information strengthens the condition

²¹The positivity conditions on quantities ensure $\tilde{\nu}^b \in (\nu^b, 1)$ and $\tilde{\nu}^c \in (\nu^c, 1)$. We refer to the proof of Proposition 1 (provided in the Appendix) for technical details.

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for allowing the merger under Cournot competition to a larger extent than the condition under Bertrand competition. This corresponds to an increase in the sensitivity of merger policy to the intensity of competition in the unregulated segment of the market. We know from Lemma 2 that the presence of asymmetric information in addition to uncertainty aggravates the regulator's informational problem and this translates into a reduction in the regulated output of the inefficient firm in order to reduce the informational rents to the efficient firm. The higher intensity of Bertrand competition mitigates the associated welfare losses to a larger extent than Cournot competition. Hence, the combination of pre-merger uncertainty and post-merger asymmetric information induces the regulator to increase the toughness of the merger challenge rule in response to softer competition in the unregulated part of the market.

As Figure 1.1 depicts, the degree of differentiation between regulated and unregulated goods affects the optimal merger policy. A higher demand interdependence results in a more lenient merger policy, irrespective of the mode of competition. This is because the competitive segment can better alleviate the allocative losses in the regulated part of market driven by informational problems. In the light of our previous discussion, it does not come entirely as a surprise that this effect is more pronounced under Bertrand than under Cournot competition, since Bertrand competitors respond more efficiently to regulatory distortions. Therefore, if we interpret the degree of substitutability as a measure of the strength of competition between regulated and unregulated firms, we can conclude that more intense competition both among unregulated firms and between regulated and unregulated firms induces a softer merger challenge rule.

It is also worth investigating the impact of an exacerbation of asymmetric information about post-merger costs on the optimal merger policy. To this aim, we consider a mean preserving spread of the original distribution function for $\theta \in \theta_h, \theta_l$, by keeping the expectation over θ constant and increasing $\Delta\theta$. For the sake of simplicity, we assume that θ_h and θ_l are equally likely, i.e., $\nu = 0.5$, which yields an expected value $\bar{\theta} = 0.5\theta_h + 0.5\theta_l$. Our result is formalized in the following corollary.

Corollary 1 *Define $\Delta\nu^k \equiv \tilde{\nu}^k - \nu^k$, $k = b, c$. Then, for $\bar{\theta} = 0.5\theta_h + 0.5\theta_l$, it holds*

1.6. DIVERSIFICATION INTO THE UNREGULATED SEGMENT

that $\frac{\partial \Delta \nu^k}{\partial \theta_h} > 0$, $k = b, c$, if θ_h is not too high.

A higher θ_h must be associated with a lower θ_l when the mean $\bar{\theta}$ remains constant. The resulting increase in $\Delta\theta$ corresponds to an aggravation of the regulator's informational problem and leads to an increase in the toughness of merger challenge rule relative to the case of only pre-merger uncertainty, irrespective of the mode of competition. This holds true if the magnitude of efficiency gains θ_h is not too high, otherwise allowing the merger is always optimal (for a given probability of efficiency gains).

1.6 Diversification into the unregulated segment

In practice, regulated firms can be active in a competitive part of the market as well. Regulated utilities that provide energy transmission and distribution often engage in competitive retail services. Regulated suppliers of basic local telephone services may also offer long-distance telephone and broadband Internet services at unregulated rates. In this section we investigate the implications for the design of the optimal merger policy that arise when regulated firms expand into a competitive segment of the market.

In line with the most common regulatory practices in Europe and in the US, we assume that the regulated activities of a firm are legally unbundled from its competitive activities. This entails separate accounts for regulated and competitive operations so that provision of each commodity is stand-alone profitable and the regulator is only allowed to control regulated activities.²² As Vickers (1995, p. 14) suggests, a realistic formulation of the participation constraint requires that, as in the absence of diversification, a firm at least break even in its regulated activities. Moreover, in the literature on legal unbundling (e.g., Cremer and De Donder 2013; Höffler and Kranz 2011; Sibley and Weisman 1998), a regulated firm is entitled to receive competitive profits but cannot interfere in the operations of the competitive affiliate, which independently maximizes its own profits. In our

²²For instance, the Telecommunications Act of 1996 provides that the US incumbent local exchange carriers can obtain a reasonable profit from regulated activities, while earnings from unregulated activities are not relevant to the definition of a reasonable profit (Sidak and Spulber 1998, Ch. 9).

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setting, the maximization of competitive profits follows irrespective of whether the affiliate cares about its own profits or total profits, since regulated profits are entirely determined by the regulatory contract.

This discussion implies that the results in the absence of a merger remain unchanged.²³ However, the regulated firms' diversification into the unregulated segment of the market can affect the incentives to strategically manipulate the private information about cost synergies after the merger, because the merged firm internalizes the impact of its behavior on the profits from competitive activities.

Since under Bertrand competition profits are competed away, the regulated firms' diversification is inconsequential and the results in Sections 1.4 and 1.5.1 are unaffected. However, Cournot competition entails positive profits, and we show that the diversification into a Cournot segment leads to new results of some interest. As in the baseline model, we consider two identical competitive firms $s = 1, 2$ in each market $i = 1, 2$, which have profits $\pi^{is}(q_{ir})$. Regulated firm i now owns one competitive subsidiary (say, firm 1) in the market where it operates, whose profits are $\pi^{i1}(q_{ir})$.²⁴ Since the subsidiary maximizes its own profits, the outcome in the competition stage is unchanged.

If the merger is allowed, the new regulated entity controls two competitive firms, one in each market. The merged firm cares about the sum of regulated and unregulated profits when manipulating its private information. Formally, the incentive compatibility constraints are

²³Such a conclusion deserves a remark. If goods are complements, the diversified regulated firm is willing to accept any regulatory contract that ensures non-negative profits from regulated activities. This is not the case under substitutability, since regulated production reduces the demand and the profits in the unregulated segment. In order to induce the regulated firm to accept the regulatory contract, the regulator could prohibit the regulated firm's diversification into the unregulated segment when it rejects a contract which guarantees non-negative regulated profits. If this is not feasible, a further constraint should be introduced, which ensures the firm's participation in the regulatory relationship. It can be shown that this additional constraint does not alter the qualitative comparison between merger challenge rules under Bertrand and Cournot competition, and therefore our main results carry over.

²⁴Our qualitative results carry over when only one regulated firm diversifies into the competitive segment. In Section 1.8 we discuss the case in which one regulated firm expands into the unregulated segment of the market where the other regulated firm operates.

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$$\begin{aligned}
\pi_{rh} + \pi^{11}(q_{1rh}) + \pi^{21}(q_{2rh}) &= T_{rh} - cq_{1rh} - cq_{2rh} + \theta_h q_{1rh} q_{2rh} + \pi^{11}(q_{1rh}) + \pi^{21}(q_{2rh}) \\
&\geq T_{rl} - cq_{1rl} - cq_{2rl} + \theta_h q_{1rl} q_{2rl} + \pi^{11}(q_{1rl}) + \pi^{21}(q_{2rl}) \\
&= \pi_{rl} + \Delta\theta q_{1rl} q_{2rl} + \pi^{11}(q_{1rl}) + \pi^{21}(q_{2rl}),
\end{aligned}$$

$$\begin{aligned}
\pi_{rl} + \pi^{11}(q_{1rl}) + \pi^{21}(q_{2rl}) &= T_{rl} - cq_{1rl} - cq_{2rl} + \theta_l q_{1rl} q_{2rl} + \pi^{11}(q_{1rl}) + \pi^{21}(q_{2rl}) \\
&\geq T_{rh} - cq_{1rh} - cq_{2rh} + \theta_l q_{1rh} q_{2rh} + \pi^{11}(q_{1rh}) + \pi^{21}(q_{2rh}) \\
&= \pi_{rh} - \Delta\theta q_{1rh} q_{2rh} + \pi^{11}(q_{1rh}) + \pi^{21}(q_{2rh}).
\end{aligned}$$

Using the profits $\pi^{i1}(q_{ir}) = \frac{(\alpha - c - \gamma q_{ir})^2}{9}$ of the merged firm's subsidiary in market i under Cournot competition, the incentive constraints can be rewritten after some manipulation as follows

$$\pi_{rh} \geq \pi_{rl} + \Delta\theta q_{1rl} q_{2rl} + \frac{\gamma}{9} \sum_{i=1}^2 (2\alpha - 2c - \gamma q_{irh} - \gamma q_{irl})(q_{irh} - q_{irl}), \quad (1.12)$$

$$\pi_{rl} \geq \pi_{rh} - \Delta\theta q_{1rh} q_{2rh} + \frac{\gamma}{9} \sum_{i=1}^2 (2\alpha - 2c - \gamma q_{irh} - \gamma q_{irl})(q_{irl} - q_{irh}). \quad (1.13)$$

Adding (1.12) and (1.13) yields

$$q_{1rh} q_{2rh} \geq q_{1rl} q_{2rl}. \quad (1.14)$$

In the following lemma we characterize the optimal regulatory policy when the merger is permitted.

Lemma 3 *Suppose that $\theta \in \{\theta_h, \theta_l\}$ is uncertain before the merger and becomes private information of the merged firm after the merger. Moreover, suppose that the merging firms diversify into the unregulated segment, where competition takes place à la Cournot. Then, if the merger is allowed, the outputs in market i are*

$$\begin{aligned}
\tilde{q}_{irh}^{mcd} &= \frac{(3 - 2\gamma)(\alpha - c)}{3 - 2\gamma^2 - 3\theta_h}, \quad \tilde{q}_{irl}^{mcd} = \frac{(9 - 4\gamma + 2\gamma\phi)(\alpha - c)}{9 - 4\gamma^2 - 9\theta_l + (2\gamma^2 + 9\Delta\theta)\phi}; \\
\tilde{q}_{iuh}^{mcd} &= \frac{6(1 - \gamma - \theta_h)(\alpha - c)}{9 - 6\gamma^2 - 9\theta_h}, \quad \tilde{q}_{iul}^{mcd} = \frac{6(1 - \gamma - \theta_l + \Delta\theta\phi)(\alpha - c)}{9 - 4\gamma^2 - 9\theta_l + (2\gamma^2 + 9\Delta\theta)\phi}.
\end{aligned}$$

The diversification into a Cournot segment crucially affects the regulatory pol-

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icy designed for the merged firm. When goods are substitutes, the efficient merged firm has a stronger incentive to claim to be inefficient, since a lower regulated quantity due to cost exaggeration improves the demand and the profits in the unregulated segment. In fact, the incentive constraint (1.12) is more severe than the constraint (1.7). As Lemmas 2 and 3 reveal, the regulator reduces the quantity of the efficient firm, $\tilde{q}_{irh}^{mcd} < \tilde{q}_{irh}^{mc}$, and it increases the quantity of the inefficient firm, $\tilde{q}_{irl}^{mcd} > \tilde{q}_{irl}^{mc}$, in order to curb the informational rents in (1.12).

The reverse occurs when goods are complements. A lower regulated quantity due to cost misrepresentation now reduces the demand and profits in the unregulated segment, which mitigates the regulator's incentive problem. As Lemmas 2 and 3 indicate, the regulator prefers to increase the wedge between the regulated output of the efficient firm and that of the inefficient firm, namely, $\tilde{q}_{irh}^{mcd} > \tilde{q}_{irh}^{mc}$ and $\tilde{q}_{irl}^{mcd} < \tilde{q}_{irl}^{mc}$, since this allows a higher rent extraction.

Equipped with the results in Lemma 3 and using (1.9), we can now formalize the optimal merger policy in the presence of diversification into a Cournot segment.

Proposition 2 *Suppose that $\theta \in \{\theta_h, \theta_l\}$ is uncertain before the merger and becomes private information of the merged firm after the merger. Moreover, suppose that the merging firms diversify into the unregulated segment, where competition takes place à la Cournot. Then,*

(i) *when goods are substitutes, i.e., $\gamma \geq 0$, there exists a threshold $\theta_h^*(\gamma) \geq 0$ (where $\theta_h^* = 0$ if and only if $\gamma = 0$) such that for $\theta_h \leq \theta_h^*$ the merger is never ex ante welfare enhancing. For $\theta_h > \theta_h^*$ the merger is ex ante welfare enhancing if and only if $\phi(\nu) > \tilde{\phi}_d^c$, where $\tilde{\phi}_d^c > 0$ is given by*

$$\frac{-(9 - 4\gamma)^2 (3 - 2\gamma^2 - 3\theta_h) \theta_l}{\Delta\theta [2\gamma (57\gamma - 8\gamma^3 - 54) + 3\theta_h (9 - 4\gamma)^2] + 2\gamma^2 [6(1 - \gamma)^2 + \theta_h (21 + 8\gamma^2 - 24\gamma)]}; \quad (1.15)$$

(ii) *when goods are complements, i.e., $\gamma < 0$, the merger is ex ante welfare enhancing if and only if $\phi(\nu) > \tilde{\phi}_d^c$.*

We know from the discussion following Lemma 3 that the regulated firms' diversification into a competitive segment complicates the regulator's incentive problem when goods are substitutes. As Proposition 2 reveals, if the magnitude

1.6. DIVERSIFICATION INTO THE UNREGULATED SEGMENT

of efficiency gains the merger may generate is small enough, the regulator prefers to block the merger tout court. Otherwise, the merger is allowed if the probability of efficiency gains is relatively high.

In order to further investigate the impact of diversification on the optimal merger policy, we rewrite the merger condition under Bertrand competition in (1.10) as

$$\phi(\nu) > -\frac{1 - \gamma^2 - \theta_h}{\theta_h \Delta \theta} \theta_l \equiv \tilde{\phi}^b = \tilde{\phi}_d^b, \quad (1.16)$$

where the equality indicates that diversification is inconsequential, and the merger condition under Cournot competition in (1.11) as

$$\phi(\nu) > -\frac{9 - 4\gamma^2 - 9\theta_h}{9\theta_h \Delta \theta} \theta_l \equiv \tilde{\phi}^c. \quad (1.17)$$

We can now state the following conclusion.

Proposition 3 *Suppose that $\theta \in \{\theta_h, \theta_l\}$ is uncertain before the merger and becomes private information of the merged firm after the merger. Then, (i) when goods are substitutes, i.e., $\gamma \geq 0$, we have $\tilde{\phi}_d^c \geq \tilde{\phi}^c \geq \tilde{\phi}^b$, where the equality holds if and only if $\gamma = 0$;*

(ii) when goods are complements, i.e., $\gamma < 0$, we have $\tilde{\phi}_d^c < \tilde{\phi}^c$. Moreover, there exists a threshold $\tilde{\theta}_h(\gamma) > 0$, with $\frac{\partial \tilde{\theta}_h}{\partial \gamma} > 0$, such that $\tilde{\phi}^b > \tilde{\phi}_d^c$ if and only if $\theta_h < \tilde{\theta}_h$.

As Figure 1.2 illustrates, when goods are substitutes the regulated firms' diversification into a Cournot segment induces the regulator to establish a more severe merger challenge rule. This is a consequence of the merged firm's stronger incentive to manipulate its private information about post-merger costs.

Things are different with complementary goods. The regulated firms' diversification under Cournot competition alleviates the regulator's incentive problem and therefore relaxes the optimal merger policy, i.e., $\tilde{\phi}_d^c < \tilde{\phi}^c$. The incentive benefits of diversification can be so large that the results derived Proposition 1 are reversed, and Cournot competition leads to a more lenient merger policy than Bertrand competition, i.e., $\tilde{\phi}^b > \tilde{\phi}_d^c$. Proposition 3 indicates that this is the case when $\theta_h < \tilde{\theta}_h$. As $\tilde{\theta}_h$ increases with γ , this condition becomes more severe with closer

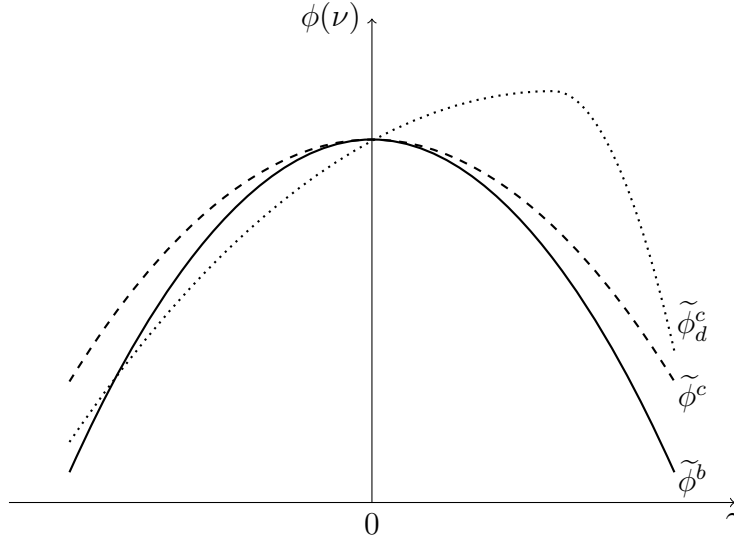


Figure 1.2: Merger policy under diversification

complements. Since a higher degree of complementarity softens the optimal merger policy irrespective of the mode of competition ($\frac{\partial \tilde{\phi}^b}{\partial \gamma} > 0$ and $\frac{\partial \tilde{\phi}_d^c}{\partial \gamma} > 0$ for $\gamma < 0$), we can conclude that, when goods are not close complements, the aforementioned incentive benefits of diversification into a Cournot segment outweigh the allocative benefits of Bertrand competition derived in Proposition 1. Conversely, when the degree of complementarity is high enough, the latter benefits tend to prevail.

The result of a more lenient merger policy under Cournot competition is even stronger in the presence of economies of scope between regulated and unregulated activities. As Calzolari and Scarpa (2014) show, a lower regulated quantity due to cost misrepresentation increases the (marginal) costs of unregulated operations, which induces the Cournot competitors of the diversified regulated firm to expand their production. Hence, Cournot competition mitigates the regulator's incentive problem and leads to a softer merger challenge rule.

1.7 Robustness

We discuss some assumptions of the model in order to gain insights into the robustness of the results.

1.7.1 Efficiency gains

Following some relevant contributions about uncertain efficiency gains (e.g., Amir et al. 2009; Choné and Linnemer 2008), we assume that antitrust authorities and merging firms share the same beliefs about the realization of cost synergies. These beliefs may arise from comparable mergers or post-merger simulations. One could argue that the merging firms might acquire some private signals that allow them to update their beliefs about cost synergies even before the merger. In practice, antitrust authorities seek to extract any superior information of the merging firms with the request of convincing documentation and reports about efficiency claims. Our qualitative conclusions carry over even when the merging firms are better informed than the regulator before the merger. The rationale is the following. As we show in Section 1.7.2, the regulated firms are always willing to merge under Bertrand competition, so that the regulator cannot update its beliefs after a merger proposal. The same occurs under Cournot competition if goods are substitutes, and therefore our results fully hold. With complementary goods, the regulator might update its information after a merger proposal only in case of diversification. This strengthens our result that the regulated firms' expansion into a Cournot segment mitigates the regulator's incentive problem and leads to a more lenient merger challenge rule.²⁵

The main informational advantage of the merging firms is that they privately learn the realization of post-merger costs. Abstracting from the complexities that arise from regulatory limited commitment, one might claim that this type of informational asymmetry is transitory by its very nature, since the regulator could revise the regulatory policy and remove any distortion in the light of the information acquired about efficiency gains. In this sense, our model provides a short-run analysis. As Amir et al. (2009) argue, this approach is justified since the short-run period is the main focus of merger investigations.²⁶

²⁵In practice, during a merger investigation antitrust authorities cannot design any contract that provides transfer payments and penalties in order to induce information revelation. Even if this were feasible, the full information outcome cannot be still achieved under some reasonable assumptions, such as the firm's limited liability.

²⁶A long-run analysis is much more demanding, since it requires the identification of other potential contributing factors, such as industry-specific or economy-wide shocks. This explains why most empirical studies consider horizons extending only 3 to 5 years.

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Furthermore, our main results hinge upon the presence of asymmetric information after the merger, which does not necessarily arise from synergies. Practitioners recognize that a merger between regulated firms tends to aggravate the regulator's informational problem. This is because after the merger it becomes more cumbersome to use benchmarking mechanisms in order to discipline the behavior of the regulated firm.

1.7.2 Firms' incentives to merge

Throughout the analysis we do not explicitly deal with the merger decision of regulated firms. This point definitely deserves some discussion. In the absence of diversification, it is immediate to see that the regulated firms have an incentive to merge, since the merger entails (expected) informational rents from privileged knowledge of efficiency gains.

This result clearly extends to the case of diversification into a Bertrand segment. To explore the diversified firms' incentives to merge under Cournot competition, we compare the expected profits from the merger with the profits in the absence of the merger that only arise from competitive activities. Using the binding incentive constraint (1.12), a merger turns out to be profitable if and only if

$$E [\tilde{\pi}_r^{mcd} + \pi^{11} (\tilde{q}_{1r}^{mcd}) + \pi^{21} (\tilde{q}_{2r}^{mcd})] = \nu \Delta \theta (\tilde{q}_{1rl}^{mcd})^2 + 2\pi^{11} (\tilde{q}_{1rl}^{mcd}) > 2\pi^{11} (q_{1r}^c),$$

where $2\pi^{11}(q_{1r}^c)$ is the aggregate profit from competitive activities in the absence of the merger. Since the post-merger regulated output of the inefficient firm is lower than the output without the merger, $\tilde{q}_{irl}^{mcd} < q_{ir}^c$, a merger is always proposed when goods are substitutes. The rationale is that the merging firms obtain (expected) informational rents from regulated activities and higher competitive profits. When goods are complements, competitive profits decline after the merger. Hence, a merger is profitable if the informational rents from regulated activities outweigh the lower profits from competitive operations.

1.8 Concluding remarks and policy implications

In this chapter we examine the welfare effects of a merger between regulated firms in the presence of two relevant informational problems, namely, uncertainty and asymmetric information about efficiency gains, when regulated firms interact with unregulated competitors. The merger between regulated firms entails a trade-off between the benefits of potential efficiency gains from joint production and the costs of distortions in the regulatory policy due to informational problems about post-merger costs. We show that, as a result of this trade-off, the optimal merger policy depends on the intensity of competition between unregulated firms. In particular, fiercer competition makes the optimal merger policy more lenient with the merging regulated firms. The rationale is that fiercer competition induces a more efficient response of unregulated firms to changes in their demand driven by distortions in the regulatory policy due to informational problems. This reduces the allocative costs of regulatory distortions and softens the optimal merger policy.

These results may be reversed if regulated firms diversify into the unregulated part of the market. When regulated and unregulated goods exhibit some degree of complementarity, the diversified merged firm has a weaker incentive to manipulate its private information about efficiencies from the merger, since a lower regulated quantity due to cost misrepresentation translates into lower demand and profits in the competitive segment. Therefore, under complementarity, the regulated firm's internalization of competitive profits relaxes the regulator's incentive problem, and weaker competition (which generates higher profits) can lead to a more lenient merger policy.

It is well established in the theoretical and practical debate that mergers in unregulated industries entail a trade-off between efficiency gains from joint production and enhanced market power of merging firms, which results from a reduction in the number of rivals competing in the market. Our analysis recommends that the study of the intensity of competition should be extended to markets where merging regulated firms interact with unregulated competitors.

Specifically, our results suggest that the merger policy involving regulated firms should be more lenient in industries where liberalized segments of the market are characterized by intense competition. This can be the case in energy sectors when

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liberalized retail services are highly competitive. In some circumstances, however, competition in liberalized segments of the market is weak, for instance because of severe capacity constraints. This can occur when unregulated competitors must undertake huge investments. If regulated firms also engage in the provision of unregulated services that are substitutes for the regulated ones, antitrust authorities should toughen their stance towards mergers between regulated firms. This could apply to regulated transportation utilities that also provide unregulated bus services. Conversely, if regulated firms also provide goods which are complements for the regulated ones, the merger between regulated firms should be assessed more favorably. This can be the case of local exchange carriers that also provide long-distance telephone services or telephone equipment.

This conclusion warrants a remark. In our analysis, we consider mergers between regulated firms which are active in different regions and may diversify into a competitive segment of the market where they operate. When a regulated firm expands into a competitive part of the market where the other firm is established, a merger clearly exhibits an anticompetitive concern stemming from the enhanced market power in the unregulated segment. In this case, antitrust authorities might approve the merger conditionally upon some structural remedies, such as the divestiture of one competitive subsidiary.

1.9 Appendix

This Appendix collects the proofs.

Proof of Remark 1. If the merger is not allowed, the two markets are fully separated. Replacing T_{ir} with π_{ir} from (1.2), the regulator's objective of maximizing welfare in market i is given by

$$\max_{q_{ir}, \pi_{ir}} (\alpha - c)q_{ir} + \alpha q_{iu}^k - \frac{1}{2}q_{ir}^2 - \frac{1}{2}(q_{iu}^k)^2 - \gamma q_{ir}q_{iu}^k - p_{iu}^k q_{iu}^k - \pi_{ir} \quad \text{s.t.} \quad \pi_{ir} \geq 0,$$

where $q_{iu}^k(q_{ir})$, $k = b, c$, is the unregulated output in the competition stage and $p_{iu}^k(\cdot)$ is the associated price. Under Bertrand competition, using $q_{iu}^b(q_{ir}) = \alpha - c - \gamma q_{ir}$ with $p_{iu}^b = c$ and taking the first-order condition for q_{ir} yields $q_{ir}^b = q_{iu}^b = \frac{\alpha - c}{1 + \gamma}$. Welfare without the merger is $CS^b = \frac{2(\alpha - c)^2}{1 + \gamma}$. Under Cournot competition, using

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$q_{iu}^c(q_{ir}) = \frac{2}{3}(\alpha - c - \gamma q_{ir})$ with $p_{iu}^c = \alpha - q_{iu}^c(\cdot) - \gamma q_{ir}$ and taking the first-order condition for q_{ir} yields $q_{ir}^c = \frac{(9-4\gamma)(\alpha-c)}{9-4\gamma^2}$ and $q_{iu}^c = \frac{6(1-\gamma)(\alpha-c)}{9-4\gamma^2}$. Welfare without merger is $CS^c = \frac{4(\alpha-c)^2}{9} + \frac{(9-4\gamma)^2(\alpha-c)^2}{9(9-4\gamma^2)}$.

If the merger is allowed, after replacing T_r with π_r from (1.3), the regulator's problem of maximizing welfare in (1.4) can be written as

$$\max_{q_{ir}, \pi_r} \sum_{i=1}^2 \left[(\alpha - c) q_{ir} + \alpha q_{iu}^k - \frac{1}{2} q_{ir}^2 - \frac{1}{2} (q_{iu}^k)^2 - \gamma q_{ir} q_{iu}^k - p_{iu}^k q_{iu}^k \right] + \theta q_{1r} q_{2r} - \pi_r$$

s.t. $\pi_r \geq 0$.

Under Bertrand competition, using $q_{iu}^b(q_{ir}) = \alpha - c - \gamma q_{ir}$ with $p_{iu}^b = c$ yields $q_{ir}^{mb} = \frac{(1-\gamma)(\alpha-c)}{1-\gamma^2-\theta}$ and $q_{iu}^{mb} = \frac{(1-\gamma-\theta)(\alpha-c)}{1-\gamma^2-\theta}$, which entails $CS^{mb} = \frac{(2-2\gamma-\theta)(\alpha-c)^2}{1-\gamma^2-\theta}$. Under Cournot competition, using $q_{iu}^c(q_{ir}) = \frac{2}{3}(\alpha - c - \gamma q_{ir})$ with $p_{iu}^c = \alpha - q_{iu}^c(\cdot) - \gamma q_{ir}$ yields $q_{ir}^{mc} = \frac{(9-4\gamma)(\alpha-c)}{9-4\gamma^2-9\theta}$ and $q_{iu}^{mc} = \frac{6(1-\gamma-\theta)(\alpha-c)}{9-4\gamma^2-9\theta}$, which entails $CS^{mc} = \frac{4(\alpha-c)^2}{9} + \frac{(9-4\gamma)^2(\alpha-c)^2}{9(9-4\gamma^2-9\theta)}$. It follows that $CS^{mb} - CS^b = \frac{(1-\gamma)(\alpha-c)^2\theta}{(1-\gamma^2-\theta)(1+\gamma)} > (<)0$ and $CS^{mc} - CS^c = \frac{(9-4\gamma)^2(\alpha-c)^2\theta}{(9-4\gamma^2-9\theta)(9-4\gamma^2)} > (<)0$ if and only if $\theta = \theta_h(\theta_l)$. ■

Proof of Lemma 1. As the regulator is fully informed in the regulatory stage, the regulatory outcomes in the proof of Remark 1 still hold. However, the regulator's merger decision now occurs before costs are realized. Under Bertrand competition, expected welfare from the merger is $E[CS^{mb}] = \nu \frac{(2-2\gamma-\theta_h)(\alpha-c)^2}{1-\gamma^2-\theta_h} + (1-\nu) \frac{(2-2\gamma-\theta_l)(\alpha-c)^2}{1-\gamma^2-\theta_l}$. Then, we find $E[CS^{mb}] > CS^b$ if and only if condition (1.5) in the lemma holds. Under Cournot competition, expected welfare from the merger is $E[CS^{mc}] = \frac{4(\alpha-c)^2}{9} + \nu \frac{(9-4\gamma)^2(\alpha-c)^2}{9(9-4\gamma^2-9\theta_h)} + (1-\nu) \frac{(9-4\gamma)^2(\alpha-c)^2}{9(9-4\gamma^2-9\theta_l)}$, and we find $E[CS^{mc}] > CS^c$ if and only if condition (1.6) in the lemma holds. Using the regulatory outcomes in the proof of Remark 1, the positivity conditions on quantities entail $\nu^b \in (0, 1)$ and $\nu^c \in (0, 1)$. Standard computations yield $\nu^c \geq \nu^b$, where the equality holds if and only if $\gamma = 0$. ■

Proof of Lemma 2. The incentive constraint (1.7) and the participation constraint $\pi_{rl} \geq 0$ imply $\pi_{rh} \geq 0$, which is therefore slack in equilibrium. Moreover, conditions (1.7) and $\pi_{rl} \geq 0$ must be binding at the optimal contract, otherwise the regulator could increase welfare via an adequate reduction in the firm's transfers. We check ex post that the incentive constraint (1.8) is satisfied, which is the case if and only if the monotonicity condition $q_{1rh}q_{2rh} \geq q_{1rl}q_{2rl}$ (that follows from

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adding (1.7) and (1.8)) holds. Substituting the binding constraints into (1.4), the regulator's maximization problem can be written after some manipulation as

$$\begin{aligned} \max_{q_{irh}, q_{irl}} \nu \left\{ \sum_{i=1}^2 \left[(\alpha - c) q_{irh} + \alpha q_{iuh}^k - \frac{1}{2} q_{irh}^2 - \frac{1}{2} (q_{iuh}^k)^2 - \gamma q_{irh} q_{iuh}^k - p_{iuh}^k q_{iuh}^k \right] \right. \\ \left. + \theta_h q_{1rh} q_{2rh} - \Delta \theta q_{1rl} q_{2rl} \right\} + (1 - \nu) \times \\ \left\{ \sum_{i=1}^2 \left[(\alpha - c) q_{irl} + \alpha q_{iul}^k - \frac{1}{2} q_{irl}^2 - \frac{1}{2} (q_{iul}^k)^2 - \gamma q_{irl} q_{iul}^k - p_{iul}^k q_{iul}^k \right] + \theta_l q_{1rl} q_{2rl} \right\}. \end{aligned}$$

Under Bertrand competition, using $q_{iu}^b(q_{ir}) = \alpha - c - \gamma q_{ir}$ with $p_{iu}^b = c$ and taking the first-order conditions for q_{irh} and q_{irl} yields $(1 - \gamma)(\alpha - c) - (1 - \gamma^2) q_{irh} + \theta_h q_{jrh} = 0$ and $(1 - \gamma)(\alpha - c) - (1 - \gamma^2) q_{irl} + \theta_l q_{jrl} - \Delta \theta \phi q_{jrl} = 0$, $i, j = 1, 2$, $i \neq j$. Under Cournot competition, using $q_{iu}^c(q_{ir}) = \frac{2}{3}(\alpha - c - \gamma q_{ir})$ with $p_{iu}^c = \alpha - q_{iu}^c(\cdot) - \gamma q_{ir}$ and taking the first-order conditions for q_{irh} and q_{irl} yields $(9 - 4\gamma)(\alpha - c) - (9 - 4\gamma^2) q_{irh} + 9\theta_h q_{jrh} = 0$ and $(9 - 4\gamma)(\alpha - c) - (9 - 4\gamma^2) q_{irl} + 9\theta_l q_{jrl} - 9\Delta \theta \phi q_{jrl} = 0$, $i, j = 1, 2$, $i \neq j$. Usual substitutions imply the results in the lemma. Since $q_{1rh} q_{2rh} \geq q_{1rl} q_{2rl}$ holds, condition (1.8) is also met. ■

Proof of Proposition 1. From Lemma 2 we find that expected welfare \widetilde{CS}^{mb} from the merger under Bertrand competition can be written as

$$\begin{aligned} (\alpha - c)^2 + \frac{\nu(1 - \gamma)^2(\alpha - c)^2}{1 - \gamma^2 - \theta_h} + \frac{(1 - \nu)(1 - \gamma)^2(\alpha - c)^2}{1 - \gamma^2 - \theta_l + \Delta \theta \phi} \\ = (\alpha - c)^2 + \frac{(1 - \gamma^2 - \theta_h + \Delta \theta \phi)(1 - \gamma)^2(\alpha - c)^2}{(1 - \gamma^2 - \theta_h)(1 - \gamma^2 - \theta_l + \Delta \theta \phi)}. \end{aligned}$$

From the proof of Remark 1 we know that welfare without the merger is $CS^b = \frac{2(\alpha - c)^2}{1 + \gamma}$. It follows that $\widetilde{CS}^{mb} > CS^b$ if and only if condition (1.10) in the proposition holds.

Expected welfare \widetilde{CS}^{mc} from the merger under Cournot competition can be written as

$$\begin{aligned} \frac{4(\alpha - c)^2}{9} + \frac{\nu(9 - 4\gamma)^2(\alpha - c)^2}{9(9 - 4\gamma^2 - 9\theta_h)} + \frac{(1 - \nu)(9 - 4\gamma)^2(\alpha - c)^2}{9(9 - 4\gamma^2 - 9\theta_l + 9\Delta \theta \phi)} \\ = \frac{4(\alpha - c)^2}{9} + \frac{(9 - 4\gamma^2 - 9\theta_h + 9\Delta \theta \phi)(9 - 4\gamma)^2(\alpha - c)^2}{9(9 - 4\gamma^2 - 9\theta_h)(9 - 4\gamma^2 - 9\theta_l + 9\Delta \theta \phi)}. \end{aligned} \quad (1.18)$$

From the proof of Remark 1 we know that welfare without the merger is $CS^c = \frac{4(\alpha-c)^2}{9} + \frac{(9-4\gamma)^2(\alpha-c)^2}{9(9-4\gamma^2)}$. It follows that $\widetilde{CS}^{mc} > CS^c$ if and only if condition (1.11) in the proposition holds. Using the results in Lemma 2, the positivity conditions on quantities entail $\tilde{\nu}^b \in (\nu^b, 1)$ and $\tilde{\nu}^c \in (\nu^c, 1)$. From (1.5) and (1.10) we obtain $\tilde{\nu}^b - \nu^b = \frac{-(1-\gamma^2-\theta_h)^2\theta_h\theta_l}{(1-\gamma^2)[\theta_h^2-(1-\gamma^2)\theta_l]\Delta\theta}$. Moreover, from (1.6) and (1.11) we find $\tilde{\nu}^c - \nu^c = \frac{-(9-4\gamma^2-9\theta_h)^2\theta_h\theta_l}{(9-4\gamma^2)[9\theta_h^2-(9-4\gamma^2)\theta_l]\Delta\theta}$. Standard computations entail $\tilde{\nu}^c - \nu^c \geq \tilde{\nu}^b - \nu^b$, where the equality holds if and only if $\gamma = 0$. Combining terms yields the result in the proposition. ■

Proof of Corollary 1 . We know from the proof of Proposition 1 that $\Delta\nu^b \equiv \tilde{\nu}^b - \nu^b = \frac{-(1-\gamma^2-\theta_h)^2\theta_h\theta_l}{(1-\gamma^2)[\theta_h^2-(1-\gamma^2)\theta_l]\Delta\theta}$ and $\Delta\nu^c \equiv \tilde{\nu}^c - \nu^c = \frac{-(9-4\gamma^2-9\theta_h)^2\theta_h\theta_l}{(9-4\gamma^2)[9\theta_h^2-(9-4\gamma^2)\theta_l]\Delta\theta}$. For $\bar{\theta} = 0.5\theta_h + 0.5\theta_l$, differentiating $\Delta\nu^b$ with respect to θ_h entails after some manipulation

$$\frac{\theta_h^4(3\Gamma_b + \theta_h) + 4\bar{\theta}^3\Gamma_b(\Gamma_b - 3\theta_h) + 2\bar{\theta}\theta_h(\theta_h^2 + 11\theta_h\Gamma_b - 2\Gamma_b^2) + \bar{\theta}\theta_h^2(\Gamma_b^2 - 15\theta_h\Gamma_b - 2\theta_h^2)}{2(\theta_h - \Gamma_b)^{-1}\Gamma_b(\bar{\theta} - \theta_h)^2[2\Gamma_b\bar{\theta} - \theta_h(\Gamma_b + \theta_h)]^2},$$

where $\Gamma_b \equiv 1 - \gamma^2$. Standard computations show that this expression is positive if θ_h is not too high (given the assumptions on the parameters of the model).

For $\bar{\theta} = 0.5\theta_h + 0.5\theta_l$, differentiating $\Delta\nu^c$ with respect to θ_h entails after some manipulation

$$\frac{27\theta_h^4(\Gamma_c + 3\theta_h) + 4\bar{\theta}^3\Gamma_c(\Gamma_c - 27\theta_h) + 2\bar{\theta}\theta_h(81\theta_h^2 + 99\theta_h\Gamma_c - 2\Gamma_c^2) + \bar{\theta}\theta_h^2(\Gamma_c^2 - 135\theta_h\Gamma_c - 162\theta_h^2)}{2(9\theta_h - \Gamma_c)^{-1}\Gamma_c(\bar{\theta} - \theta_h)^2[2\Gamma_c\bar{\theta} - \theta_h(\Gamma_c + 9\theta_h)]^2},$$

where $\Gamma_c \equiv 9 - 4\gamma^2$. Standard computations show that this expression is positive if θ_h is not too high (given the assumptions on the parameters of the model). ■

Proof of Lemma 3. In line with the proof of Lemma 2, we consider the incentive constraint (1.12) and the participation constraint $\pi_{rl} \geq 0$ binding at the optimal contract, otherwise the regulator could increase welfare via a reduction in the firm's transfers. We check ex post that the incentive constraint (1.13) is satisfied, which is the case if and only if the monotonicity condition (1.14) holds, and that the participation constraint $\pi_{rh} \geq 0$ is also satisfied. Substituting the binding

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constraints into (1.4), the regulator's maximization problem becomes

$$\begin{aligned} \max_{q_{irh}, q_{irl}} \nu & \left\{ \sum_{i=1}^2 \left[(\alpha - c) q_{irh} + \alpha q_{iuh}^k - \frac{1}{2} q_{irh}^2 - \frac{1}{2} (q_{iuh}^k)^2 - \gamma q_{irh} q_{iuh}^k - p_{iuh}^k q_{iuh}^k \right] \right. \\ & + \theta_h q_{1rh} q_{2rh} - \Delta \theta q_{1rl} q_{2rl} - \frac{\gamma}{9} \sum_{i=1}^2 (2\alpha - 2c - \gamma q_{irh} - \gamma q_{irl}) (q_{irh} - q_{irl}) \left. \right\} + (1 - \nu) \\ & \times \left\{ \sum_{i=1}^2 \left[(\alpha - c) q_{irl} + \alpha q_{iul}^k - \frac{1}{2} q_{irl}^2 - \frac{1}{2} (q_{iul}^k)^2 - \gamma q_{irl} q_{iul}^k - p_{iul}^k q_{iul}^k \right] + \theta_l q_{1rl} q_{2rl} \right\}. \end{aligned}$$

Using the Cournot outcome $q_{iu}^c(q_{ir}) = \frac{2}{3}(\alpha - c - \gamma q_{ir})$ with $p_{iu}^c = \alpha - q_{iu}^c(\cdot) - \gamma q_{ir}$, the first-order conditions for q_{irh} and q_{irl} are $(9 - 6\gamma)(\alpha - c) - (9 - 4\gamma^2)q_{irh} + 9\theta_h q_{jrh} + 2\gamma^2 q_{irh} = 0$ and $(9 - 4\gamma)(\alpha - c) - (9 - 4\gamma^2)q_{irl} + 9\theta_l q_{jrl} - 9\Delta\theta\phi q_{jrl} - 2\gamma^2\phi q_{irl} = 0$, $i, j = 1, 2$, $i \neq j$, respectively. Usual substitutions imply the results in the lemma. For $\gamma \geq 0$, sufficient condition for (1.14) to be satisfied is $\theta_l \leq \frac{1}{3}(\sqrt{3} - 2)$. Alternatively, we must have $\theta_h \geq 2\gamma \frac{1-\gamma}{9-4\gamma}$. For $\gamma < 0$, condition (1.14) is always satisfied. Furthermore, for $\gamma \geq 0$, the participation constraint $\pi_{rh} \geq 0$ is always satisfied. For $\gamma < 0$, sufficient, but not necessary, condition for $\pi_{rh} \geq 0$ to be satisfied is that $|\gamma|$ is not too high. ■

Proof of Proposition 2. It follows from Lemma 3 expected welfare \widetilde{CS}^{mcd} from the merger is given by

$$\frac{4(\alpha - c)^2}{9} + \frac{\nu(3 - 2\gamma)^2(\alpha - c)^2}{3(3 - 2\gamma^2 - 3\theta_h)} + \frac{(1 - \nu)(9 - 4\gamma + 2\gamma\phi)^2(\alpha - c)^2}{9[9 - 4\gamma^2 - 9\theta_l + (2\gamma^2 + 9\Delta\theta)\phi]}.$$

Combining terms yields

$$\frac{4(\alpha - c)^2}{9} + \frac{[(9 - 4\gamma)^2 + 4\gamma^2\phi](3 - 2\gamma^2 - 3\theta_h) + 3(3 - 2\gamma)^2(2\gamma^2 + 9\Delta\theta)\phi}{9(3 - 2\gamma^2 - 3\theta_h)[9 - 4\gamma^2 - 9\theta_l + (2\gamma^2 + 9\Delta\theta)\phi]}(\alpha - c)^2. \quad (1.19)$$

From the proof of Remark 1 we know that welfare in the absence of the merger is $CS^c = \frac{4(\alpha - c)^2}{9} + \frac{(9 - 4\gamma)^2(\alpha - c)^2}{9(9 - 4\gamma^2)}$. Taking the difference between \widetilde{CS}^{mcd} and CS^c , we obtain after some manipulation

$$\begin{aligned} & 9(9 - 4\gamma)^2(3 - 2\gamma^2 - 3\theta_h)\theta_l + \phi \{ \Delta\theta [2\gamma(57\gamma - 8\gamma^3 - 54) + 3\theta_h(9 - 4\gamma)^2] \\ & + 2\gamma^2 [6(1 - \gamma)^2 + \theta_h(21 + 8\gamma^2 - 24\gamma)] \}, \end{aligned}$$

which is negative if the expression in curly brackets is negative. When goods are

substitutes, i.e., $\gamma \geq 0$, this is the case for $\theta_h \leq \theta_h^*(\gamma)$, with

$$\begin{aligned} \theta_h^* &\equiv \frac{4\gamma - 4\gamma^2 + 9\theta_l - 4\gamma\theta_l}{2(9 - 4\gamma)} + \\ &\quad \frac{\sqrt{9\theta_l[8\gamma(2\gamma - 3\theta_l) - 3(8\gamma - 9\theta_l)] + 16\gamma^2\theta_l[2\gamma(3 - 2\gamma) + 3\theta_l]}}{2\sqrt{3}(9 - 4\gamma)} \\ &\geq 0, \end{aligned}$$

where the equality holds if and only if $\gamma = 0$. For $\theta_h > \theta_h^*$, we have $\widetilde{CS}^{mcd} > CS^c$ if and only if condition (1.15) in the proposition holds. When goods are complements, i.e., $\gamma < 0$, the expression in curly brackets is always positive. Then, we find $\widetilde{CS}^{mcd} > CS^c$ if and only if condition (1.15) holds. ■

Proof of Proposition 3. Taking the difference between \widetilde{CS}^{mcd} in (1.19) and \widetilde{CS}^{mc} in (1.18) yields $\widetilde{CS}^{mcd} - \widetilde{CS}^{mc} \leq 0$ if and only if $\gamma \leq 0$. This is because the regulator faces the same maximization problem, subject to the same participation constraints, while the incentive constraint (1.12) is stronger (weaker) than (1.7) for $\gamma > (<) 0$ (the constraints (1.8) and (1.13) are implied by the monotonicity condition (1.14)). Then, we have $\tilde{\phi}_d^c \geq \tilde{\phi}^c$ if and only if $\gamma \leq 0$. Alternatively, this result follows from the comparison between (1.15) and (1.17). Using Proposition 1, we find for $\gamma \geq 0$ that $\tilde{\phi}_d^c \geq \tilde{\phi}^c \geq \tilde{\phi}^b$, where the equality holds if and only if $\gamma = 0$. For $\gamma < 0$, using (1.15) and (1.16), we find $\tilde{\phi}^b > \tilde{\phi}_d^c$ if and only if $\theta_h < \tilde{\theta}_h(\gamma)$, where $\tilde{\theta}_h \equiv \frac{2(1-\gamma^2)(54-57\gamma+8\gamma^3)}{3[36-\gamma(65-24\gamma)]} > 0$. Standard computations yield $\frac{\partial \tilde{\theta}_h}{\partial \gamma} = 6 \frac{(65-48\gamma)(54-57\gamma-54\gamma^2+65\gamma^3-8\gamma^5)}{(108-195\gamma+72\gamma^2)^2} - 2 \frac{57+108\gamma-195\gamma^2+40\gamma^4}{108-195\gamma+72\gamma^2} > 0$, where the inequality follows from the assumptions on the parameters of the model. ■

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Chapter 2

Mergers with structural remedies in a Cournot oligopoly

2.1 Introduction

Since the 1990s, when firms intend to merge, in addition to the “traditional” option to provide a merger proposal that the antitrust authority can either clear or block, the firms can also provide a merger proposal with remedies (or “commitments”), so that the antitrust authority can approve it in line with remedies. In the European Union, after the European Commission’s “Notice on remedies” (2001), and in the US, after the Federal Trade Commission’s “A Study of the Commission’s Divestiture Process” (1999), a considerable proportion of mergers is approved with remedies. For example, the European Commission’s Commission Staff Working Document (2014) states that “commitments are crucial instruments of merger control, since the large majority of cases that raise competition concerns are cleared with commitments rather than prohibited”. There are similar trends in merger cases outside the European Union and the US.

The purpose of remedies is that if the antitrust authority has concerns that a full merger may significantly affect competition in the common market (or a substantial part of it), certain modifications via remedies can guarantee continued competition. If the merger is cleared, it may impede competition, but if it is blocked, society cannot enjoy efficiency gains from the merger. Hence, a merger

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with remedies can be a golden mean between full merger and no merger.

There are two types of remedies: structural remedies and behavioral remedies. There is no generally accepted definition of structural and behavioral remedies in the literature. In this chapter we use the definitions formulated by Motta et al. (2003). Structural remedies modify the allocation of property rights and create new firms or enhance one or more existing firms. They include the divestiture of an entire on-going business or partial divestiture. Behavioral remedies entail the limitation of the merged entity's conduct.

Although both types of remedies have their pros and cons, there is a consensus that competitive concerns in horizontal mergers can be solved better by a structural remedy (OECD 2011). The EU Remedy Notice (2008) states that “the most effective way to restore effective competition, apart from prohibition, is to create the conditions for the emergence of a new competitive entity or for the strengthening of existing competitors via divestiture”. On the other hand, behavioral remedies would absorb the scarce resources of the antitrust authority since they require intensive monitoring. The remedial action chosen by the Federal Trade Commission in the US follows a relatively similar pattern. The empirical literature, as summarized in the Table 2.1 by Bougette and Turolla (2008), has also shown that structural remedies constitute the most frequent type of remedies.

	Structural	Behavioral	Mixed	Total
Phase I (in percentage of Phase I)	62 (54)	36 (31)	17 (15)	115
Phase II (in percentage of Phase II)	26 (36)	18 (25)	28 (39)	72
Total	88	54	45	187

Table 2.1: Types of remedies in the European merger cases (1990-2005)

This chapter investigates structural remedies, with a focus on divestitures of one special form of assets: the divestiture of differentiated brands to an existing competitor. According to the merger guidelines issued by the UK Competition Commission (2008), “remedies that provide access to intellectual property (IP) by licensing or assignment of patents, *brands* or other IP rights may be viewed in general as a specialized form of asset divestiture”. Mergers with brand divestitures are quite common nowadays, especially in large mergers. A prominent example is the acquisition of EMI Music by Universal Music Group, two of the four global

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major record companies with a value of \$1.9 billion in 2012. In compliance with the conditions of the European Commission, Universal Music Group sold Mute catalogue to BMG, which constitutes the first completed divestment from EMI Music buyout. Moreover, the merged entity sold Parlophone Music Group (minus the Beatles) to Warner Music Group and numerous other music brands to other existing competitors or new firms.

Williamson (1968) investigates the welfare trade-off between market power and efficiency gains generated by a merger. We prove that, in line with merger cases in the recent 20 years, remedies in merger policy are powerful tools to lessen the merged entity's market power. We investigate the important role of remedies in merger policy which can increase the scope for privately and socially desirable mergers. In particular, we show that when goods are closer to perfect substitutability, then the merging firms are more inclined to give some brands to competitor(s), because the markup on each brand is lower. Therefore the range of the efficiency gains which allows the merger with remedies to be approved is larger.

Despite of the practical evidence and the empirical case studies about the impact of remedies (e.g., Duso et al. 2011, 2013), still not enough attention has been devoted to the theoretical analysis of structural remedies.

Medvedev (2007) shows that if there are three firms in a homogenous good market, the remedies with efficiency gains could extend the scope for merger acceptance. We extend this result to a differentiated good market and discuss the case of more than three firms. Vasconcelos (2010) analyzes remedies for four firms with efficiency gains. He finds that remedies may not serve consumer surplus as the antitrust authority is overshooting in terms of consumer protection, and an “over-fixing problem” can be caused by the antitrust authority. This phenomenon emerges when the antitrust authority over-fixes the anticompetitive effects of a merger and requires remedies even if the original merger (if unconditionally approved) would be consumer surplus improving. In our chapter, we abstract from this “over-fixing problem”, because in line with the antitrust practices in most industrialized countries, we focus on the merger process instead of antitrust process, which implies that remedies are endogenously provided by merging firms.

Cabral (2003) analyzes mergers in a differentiated industry with free entry. If assets are sold to an entrant firm as a remedy, then a “buy them off” effect follows

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which means that an entrant firm is dissuaded from opening a new store (or introducing a new product variant). That effect may reduce the welfare of consumers, who are better off when more variants are offered. On the contrary, Dertwinkel-Kalt and Wey (2015) analyze the effects of structural remedies on merger activity in a Cournot oligopoly with a homogenous good and find that the divestiture to an entrant firm is most effective in terms of consumer surplus. Our model focuses on the divestiture to the existing competitor(s) and excludes the entrant firm(s), so we can avoid this “buy them off” effect. This assumption is also in line with the empirical literatures (e.g., Papandropoulos and Tajana 2006) that most of new entrants cannot survive in the market for long time even when they are given the divestitures by the merged entities.

The rest of the chapter proceeds as follows. Section 2.2 sets out the basic model. Section 2.3 provides the no merger case as a benchmark. Section 2.4 analyzes the conditions for approving a merger when there are three pre-merger firms and divestiture is given. Section 2.5 considers conducts the optimal divestiture which is endogenously proposed by merging firms. Section 2.6 studies a more general setting where before merger there are four firms in a market. Finally, section 2.7 concludes and provides some future research directions. All formal proofs are collected in the Appendix.

2.2 The model

Setting There are three symmetric Cournot oligopolists indexed by $j \in \{1, 2, 3\}$ in a market. Each firm produces $n \geq 2$ brands of substitute goods. To simplify the notation, firm j produces the j th n brands, so in total there are $3n$ brands produced in the market.¹ Consider a one-shot bilateral merger with firm 1 as an acquirer and firm 2 as a target firm. We model the efficiency gains in a reduced form, as the merged entity enjoys the efficiency gains $X > 0$ from the merger. For example, X can be treated as efficiency gains based on the saving of fixed cost. Assume that the brands of the target firm may be given to the competitor, firm

¹One brand is associated with one good.

2.2. THE MODEL

3.² The number of brands that the merged entity keeps is k , where $k \in (n, 2n]$.

Following Shubik and Levitan (1980), the gross consumer surplus is specified as

$$U(q_1, \dots, q_{3n}) = \sum_{i=1}^{3n} q_i - \frac{3n}{2(1+\mu)} \left[\sum_{i=1}^{3n} q_i^2 + \frac{\mu}{3n} \left(\sum_{i=1}^{3n} q_i \right)^2 \right], \quad (2.1)$$

where q_i is the quantity of the i th brand, and $\mu > 0$ represents the degree of substitutability within the $3n$ brands.³

Maximizing the utility function (2.1) subject to the income constraint yields the inverse demand function

$$p_i(q_1, \dots, q_{3n}) = 1 - \frac{1}{1+\mu} \left(3nq_i + \mu \sum_{l=1}^{3n} q_l \right). \quad (2.2)$$

Firm j 's profit is

$$\Pi_j = \sum_{i=1}^B [p_i(q_1, \dots, q_{3n})q_i], \quad (2.3)$$

where B is the number of brands that firm j has.⁴

Timing and equilibrium concept The sequence of events unfolds as follows.

- (I) Merging firms hand in merger proposal (with or without remedies) to the antitrust authority.
- (II) The antitrust authority decides whether to approve the merger or not.
- (III) Competition takes place.

This timing is in line with the European Commission's Merger Control Procedures⁵ and reflects merging procedures in most countries and areas. In the

²In practice, the merged entity should *sell* their divestitures to other firm(s). However, in our model there is no discount factor of the transaction, so the transfer of trading divestiture is completely internalized in social welfare. Moreover, we exclude the free entry. So firm 3 is the unique possible firm which can get divestitures from the merged entity.

³Consumers preferences can be expressed as $V = U + y$, so a partial equilibrium analysis is fully justified.

⁴The cost is normalized to 0.

⁵Here we only focus on "Phase I" stage and ignore "Phase II" stage in the EU, because there are very few merger cases go to "Phase II" stage, for example, Verge (2010) shows that 3.4% of

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following, we emphasize some remarks.

It is important to distinguish between merger process and antitrust process. This paper focuses on the merger process. The crucial difference is that in the merger process the merging firms provide a merger proposal (with or without remedies), and then the antitrust authority decides to approve or block it. In the antitrust process, the antitrust authority assigns firms some remedial requirements. Put differently, in the merger process, the merger policy is not an industrial policy, the antitrust authority is not an industrial regulator, and the antitrust authority's purpose is not to re-structure the post-merger market. This is consistent with the merger procedures in most countries and areas. For example, the European Commission (2013) states that “if the Commission has concerns that the merger may significantly affect competition, *the merging companies* may offer remedies (“commitments”), i.e., propose certain modifications to the project that would guarantee continued competition on the market”.⁶ Therefore during the merging procedure the antitrust authority will not increase “over-fixing” stage problem mentioned in some contributions (e.g., Nocke and Whinston 2010), it only has a veto over merger proposals.⁷

The object of the antitrust authority is social welfare. This is in line with the antitrust practice in some countries, such as in Canada, Australia and New Zealand, the antitrust authorities lean to a social welfare standard (Motta 2004, Ch. 1). Secondly, even in the EU and the US where the antitrust authorities tend to adopt a consumer surplus standard, in some cases, they review mergers under a different (public interest) standard and the interactions among agencies with overlapping jurisdictions affect the review process in various ways (e.g., European Commission 2004, Article 11).

In principle, remedial divestiture can be assigned to already existing competitor(s) or to new entrant(s). In this paper, we only consider the merger with divestiture to an existing competitor. This assumption rules out the “buy them

mergers notified between 1999 and 2008 went into Phase II. Moreover, the rules in “Phase I” stage and “Phase II” stage are slightly different. In “Phase II” stage, merging firms and the antitrust authorities may bargain over remedies (Wood 2003). In the US, the similar two-stage procedure is called “First Request” stage and “Second Request” stage.

⁶Emphasis added.

⁷At least in “Phase I” stage.

off" effect described in Cabral (2003), which means an new entrant is unwilling to introduce a new product variant. Moreover, most of new entrants cannot survive in the market for long time (e.g., Papandropoulos and Tajana 2006).

We adopt the Subgame Perfect Nash Equilibrium (SPNE) as the equilibrium concept and solve the game with backward induction.

2.3 No merger

The benchmark solution is the three-firm Cournot oligopoly equilibrium without merger.

Lemma 4 *The pre-merger firm's profit is $\pi^{NM} = [(1 + \mu)(3 + \mu)] / [(6 + 4\mu)^2]$. The pre-merger social welfare is $SW^{NM} = U^{NM} = [3(1 + \mu)(9 + 5\mu)] / [2(6 + 4\mu)^2]$.*

Lemma 4 does not only shows the equilibrium of pre-merger market, but also unfolds the results when the antitrust authority blocks the merger.

2.4 Merger with given divestiture

The number of brands that the merged entity can keep is $k \in (n, 2n]$. When $k = 2n$, it is a full merger (merger without remedies). On the other hand, k must be higher than n , because brands are only given from target firm (firm 2) and no merged entity keeps less brands than what the pre-merger acquirer (firm 1) has.

Lemma 5 *The antitrust authority approves merger with a given divestiture, if and only if*

$$X \geq U^{NM} - U(k) \equiv X_U^*(k). \quad (2.4)$$

The function $X_U^*(k)$ plays a crucial role in the analysis and therefore we discuss its properties. $X_U^*(k) = U^{NM} - U(k)$ is U -shaped and symmetric at $k = \frac{3}{2}n$. This follows because $U(k)$ is inverted U -shaped, symmetric and maximized at $k = \frac{3}{2}n$. From a consumers' point of view, the "best" result is that the two post-merger firms share these $3n$ brands equally. The further k departs from $\frac{3}{2}n$ (whatever

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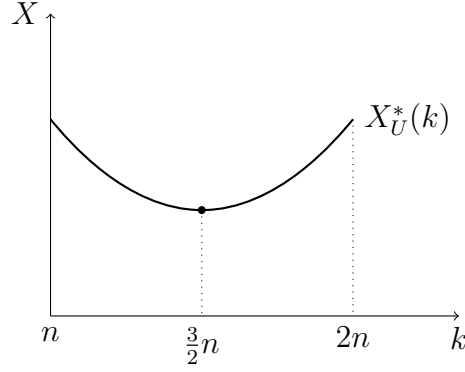


Figure 2.1: Merger with exogenous divestiture

to which direction), the smaller consumers' utility. More precisely, if the merged entity keeps $(\frac{3}{2}n + d)$ brands, where $d \in (0, \frac{1}{2}n)$, the unique competitor will keep $(\frac{3}{2}n - d)$ brands, because the number of total brands does not change before and after merger. Then the antitrust authority, which cares about the social welfare, is indifferent whether the merged entity or the competitor keeps $(\frac{3}{2}n - d)$ varieties and $(\frac{3}{2}n + d)$ varieties, respectively.

Given k , the antitrust authority can determine the value of $X_U^*(k)$. Then, as long as $X \geq X_U^*(k)$, i.e., the condition (2.4) is fulfilled, the antitrust authority approves the merger with remedies, as showed in the area above the curve $X_U^*(k)$ in Figure 2.1. When $k = \frac{3}{2}n$, the two post-merger firms share the brands equally. This is the best scenario for consumers, and the requirement for the efficiency gains is the most relaxed. When $k = n$ or $k = 2n$, they are the symmetrically worst cases for consumers, so the antitrust authority sets the hardest condition on the efficiency gains to the merging entity. When the efficiency gains X cannot fulfill the antitrust authority's conditions, which is the white area below the curve $X_U^*(k)$, the merged entity's lessened market power by remedies still overwhelms the efficiency gains from merger, so that the social welfare is reduced and the merger is blocked even with remedies.

2.5 Merger with endogenous divestiture

We next consider the case where the divestiture to a competitor is endogenously proposed by merging firms. The merging firms' purpose is to find the optimally acceptable brands they will keep to maximize the merged entity's profit, which means first the merging firms have incentive to merge, second the antitrust authority approves the merger. The constraint (2.4) still works in this section, meanwhile another constraint ensures that the merging firms have incentives to hand in the merger proposal, which means the the merged entity's net profit is not less than their joint pre-merger profits,

$$\Pi_m(k) + X \geq 2\Pi^{NM}. \quad (2.5)$$

Rewriting constraint (2.5) yields

$$X \geq 2\Pi^{NM} - \Pi_m(k) \equiv X_{\Pi}^*(k). \quad (2.6)$$

$X_{\Pi}^*(k)$ is decreasing in k , because $\Pi_m(k)$ is increasing in k . This indicates that the more brands the merged entity can keep, the higher profit it gets, as it can produce more brands with the efficiency gains X . The higher profit induces that the merging firms set more relaxed barrier to hand in their proposal.

The merging firms' maximization problem is

$$\max_k \Pi_m(k) + X \text{ s.t. (2.4) and (2.6).}$$

According to the features of $\Pi_m(k)$ discussed above, if there were no constraints on merging firms, one can get the optimal solution immediately: $k^* = 2n$, which means that the merged entity keeps all brands from both the acquirer and the target firm. Therefore, this maximization problem can be translated into two steps. First, the merging firms find out the feasible and acceptable range of k . Second, the maximal k from the range is the optimal solution of the maximization problem.

Proposition 4 *The merger decisions with optimal endogenous divestiture are following:*

A. *The merger without remedies (full merger) is cleared if and only if $X \geq X_{\Pi}^*(2n)$.*

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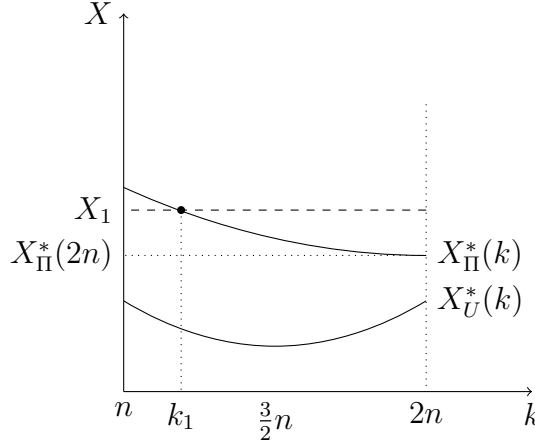


Figure 2.2: the merger case without remedies

B. The merger with remedies (the divestiture of brands to the existing competitor) is cleared if

- (i) $\mu < \mu_1$ and $X \in [X_U^*(\tilde{k}), X_U^*(2n))$, where $\tilde{k} \in (\frac{3}{2}n, 2n)$ and $\mu_1 = \frac{1}{2}(7 + \sqrt{97})$;
- (ii) $\mu \geq \mu_1$ and $X \in [X_U^*(\frac{3}{2}n), X_U^*(2n))$

The merged entity has $\max \{X_U^{-1}(X), \frac{3}{2}n\}$ brands.*

C. The merger is blocked if

- (i) $\mu < \mu_1$ and $X \in (0, X_U^*(\tilde{k}))$, where $\tilde{k} \in (\frac{3}{2}n, 2n)$;
- (ii) $\mu \geq \mu_1$ and $X \in (0, X_U^*(\frac{3}{2}n))$.

When constraints (2.4) and (2.6) are both fulfilled, the efficiency gains X must locate above both curves $X_\Pi^*(k)$ and $X_U^*(k)$. In the following, we first explain Proposition 4 with figures.

Figure 2.2 shows the case that the merging firms only provide a full merger proposal and the antitrust authority always approves the merger. For example, if the merging firms' efficiency gains is $X = X_1$, the feasible range of the number of brands that they can keep is $k \in [k_1, 2n]$. In the feasible range, the optimal k to maximize the merging firms' profit is $2n$. This rationale that the full merger is approved goes through when $X \geq X_\Pi^*(2n)$. In this case, the antitrust authority welcomes mergers more than the firms, because the condition that the antitrust authority sets to the efficiency gains is always lower than the one set by firms. So

2.5. MERGER WITH ENDOGENOUS DIVESTITURE

as long as efficiency gains are not high enough, i.e., $X < X_{\Pi}^*(2n)$, firms will not provide merger proposals at all. Based on the form of the utility function and the conditions on the parameters, this case does not hold, i.e., it is impossible that the merging firms only face two options: a full merger and no merger. There are always some scopes for a merger with remedies. In the following, we consider the possible merger cases with remedies.

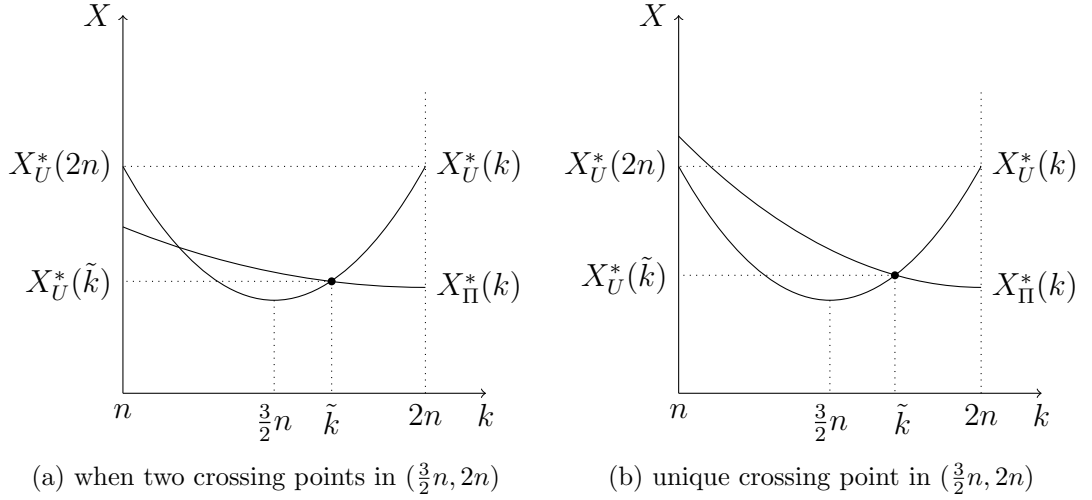


Figure 2.3: the merger case with partial remedies

Figure 2.3 shows that when μ is low enough, i.e., $\mu < \mu_1$, there is one crossing point $k = \tilde{k}$ lies between $\frac{3}{2}n$ and $2n$, whatever there is another crossing point lies between $(n, \frac{3}{2}n)$ or not. In these two cases, we can divide X into three ranges. When X is high enough, i.e. $X \geq X_U^*(2n)$, the full merger is approved. When X is at the middle range, i.e. $X_U^*(\tilde{k}) \leq X < X_U^*(2n)$, merger with remedies are approved and $k = X_U^{*-1}(X)$ and $k \in [\tilde{k}, 2n)$. When X is low enough, i.e. $X < X_U^*(\tilde{k})$, merger is blocked or the firms do not provide any merger proposal. This shows that although we define the range of k as $(n, 2n]$, actually the feasible range is $k \in [\frac{3}{2}n, 2n]$, because $k \in [\tilde{k}, 2n) \subset [\frac{3}{2}n, 2n]$. The intuition is that remedies are proposed by merging firms. Put differently, the “worst acceptable” remedies that merging firms can make is to keep $\frac{3}{2}n$ varieties, i.e., to have same number of brands as their unique competitor after merger.

The rationale is same as the following two cases showed in Figure 2.4. The

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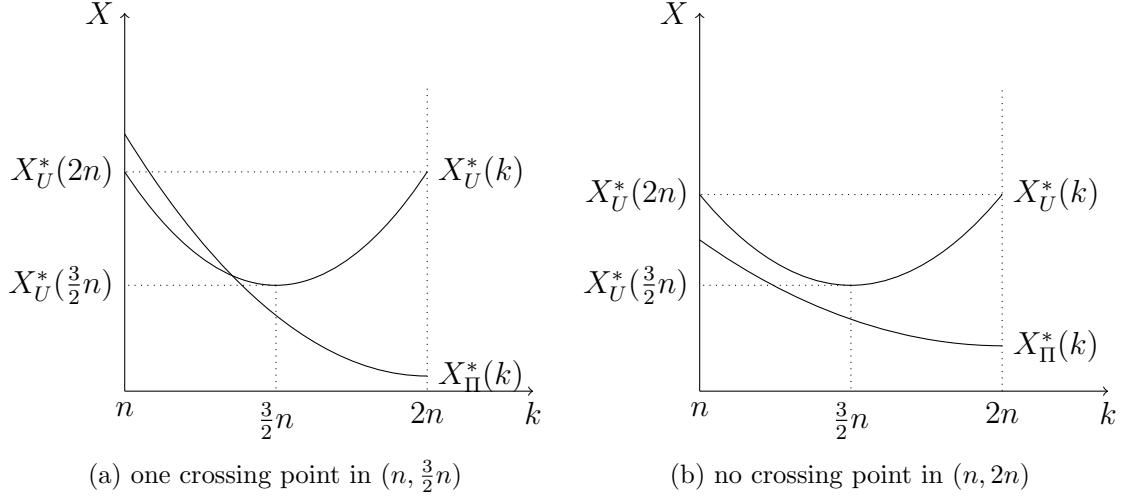


Figure 2.4: the merger case with all possible remedies

condition on the efficiency gains for the full merger does not change. Because the two cases showed in Figure 2.4 indicate the situation that μ is high enough, i.e., the brands are closer to perfect substitutes, then the competition between the two firms after merger is lighter than the one with more independent goods, the ranges of approved merger with remedies are enlarged and the ranges of block the merger are smaller than Figure 2.3, as showed in Figure 2.4 the entire range of $[\frac{3}{2}n, 2n]$ is feasible for merger with remedies.

Simplifying the cases showed in Figure 2.3 and Figure 2.4, one can focus on range $k \in [\frac{3}{2}n, 2n]$ and get Figure 2.5. The thick curves show the paths of optimal k .

Summarizing Proposition 4, we have Table 2.2.

	block	merger with remedies	full merger
$\mu < \mu_1$	$X \in (0, X_U^*(\tilde{k}))$	$X \in [X_U^*(\tilde{k}), X_U^*(2n))$	$X \in [X_U^*(2n), \infty)$
$\mu \geq \mu_1$	$X \in (0, X_U^*(\frac{3}{2}n))$	$X \in [X_U^*(\frac{3}{2}n), X_U^*(2n))$	

Table 2.2: The conditions for mergers in 3-pre-merger-firms case

Table 2.2 shows clearly that, without remedies, the merger is privately and socially desirable only when the efficiency gains X is high enough, merger with

2.5. MERGER WITH ENDOGENOUS DIVESTITURE

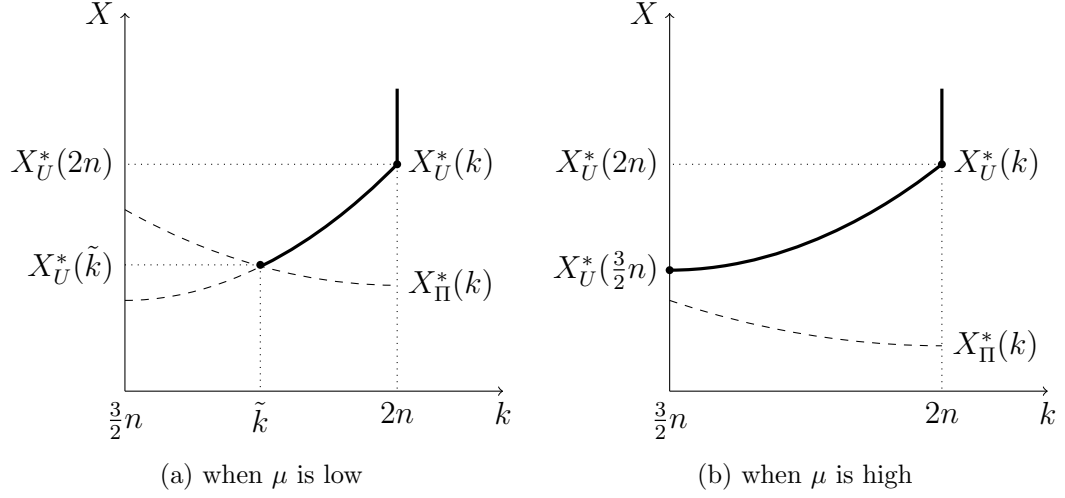


Figure 2.5: The path of optimal k

remedies is a powerful and efficient tool to lessen the merged entity's market power, so that the requirement on efficiency gains to approve the merger is much lower. As a consequence, merger with remedies increases the scope for privately and socially desirable mergers.

Another significant difference between our model and the most of existing theoretical literatures on merger with remedies is that we consider the differentiated goods rather than homogenous goods. As Proposition 4 shows, the degree of substitutability μ also plays an important role in the merger policy. When μ is high enough, i.e., the brands are closer to the perfect substitutes goods, the scope of approved merger is larger than the case that the brands are closer to the independent goods. One intuition might be that when the brands are closer to independent goods, then the requirements on approving merger should be lighter, and our result is counterintuitive. But that intuition is not complete. In our model, we consider that all the brands in the market are symmetrical substitutes goods, so the brands that the competitor are also the substitutes goods. And this is why we have that when μ is higher than the benchmark μ_1 , the range of approved merger is larger.

2.6 Extensions

If the number of firms is higher than three, the merging firms does not only decide how many divestitures gives to competitor(s), but also how to distribute a certain amount of divestitures among competitors. Consider now four symmetric pre-merger firms. All the assumptions are same as in the case of three pre-merger firms, but the total number of brands in the market is $4n$ now. Consider a one-shot merger between firm 1 as an acquirer and firm 2 as a target firm. The merged entity has two options: either to give divestitures to one of the two competitors, namely, firm 3, or to divide divestitures to both competitors, firm 3 and firm 4.

Lemma 6 *If there are four symmetric pre-merger firms,*

- A. When $\mu > \bar{\mu}(n)$, the merged entity gives the divestitures to only one competitor.*
- B. When $\mu < \bar{\mu}(n)$, the merged entity gives the divestitures symmetrically to both competitor.*

Lemma 6 shows the benchmark of two extreme cases, the merged entity either gives the divestitures to one competitor or shares the divestitures equally between the two competitors. The intuition is that, when the brands are closer to perfect substitutes, the merged entity prefers to give the divestitures to one competitor, in the sense that only makes one competitor more efficient and keeps another one same as pre-merger. When the brands are closer to independent goods, the merged entity prefers the more symmetric competition in the market. Moreover, when the merged entity gives the divestitures to only one competitor, it is similar with Proposition 4, only the values of benchmarks change. When the merged entity gives the divestitures to both competitor, another question arises: how to distribute a certain amount of divestitures among competitors, which is more complicated. The intuitions are following. The “best” result for consumers should be all the three post-merger firms share the brands equally, so in this case $X_U^*(k)$ is minimized at $k = \frac{4}{3}n$. But meanwhile even when the merged entity keeps $k = \frac{4}{3}n$ brands, it is possible that the number of brands that other two competitors have is not $\frac{4}{3}n$, because the merged entity may not distribute $\frac{2}{3}n$ brands as divestitures equally between firm 3 and firm 4.

2.7 Concluding remarks

In this chapter we attempt to shed some light on merger policy with structural remedies, a field of research which is in line with the practical trends of mergers in recent 20 years but on which still there is very few theoretical literature. To the best of our knowledge, this is the first theoretical paper which tries to analyze one popular merger trend in practice: mergers with structural divestitures of brands to the existing competitor(s). In general, merger with remedies, as a powerful tool in merger policy, increases the scope for profitable mergers because of the efficiency gains from merger, meanwhile does not harm social welfare because of the merged entity's lessened market power, so the merger with remedies is both privately and socially desirable. More precisely, the remedial offers must be larger when the merger's efficiency gains is smaller, which mirrors the proportionality principle in remedy regulations. Another important result is that when goods are closer to perfect substitutability, then the merging firms are more inclined to give some brands to competitor(s), because the markup on each brand is lower. Therefore the range of the efficiency gains which allows the merger with remedies to be approved is larger. This paper provides theoretical suggestions to the antitrust authority and shows that there is some room for the antitrust authority to improve social welfare.

Except for the more general case we discussed in Section 2.6, there is some scope for further research. For example, this paper models Phase I in the EU or First Request in the US. However, as mentioned before, there is (small) portion of merger cases which goes to Phase II or Second Request. As Farrell (2003) points out, this second phase is characterized by a bargaining process between the merging firms and the antitrust authority. We expect that some merger proposals, which are blocked under the setting of this paper, could be cleared if further negotiations are allowed between the merging firms and the antitrust authority.

2.8 Appendix

This Appendix collects the proofs.

Proof of Lemma 4. Based on the more general gross profit function 2.3, one

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can get the pre-merger firm's gross profit as $\Pi_j = \sum_{i=(j-1)n+1}^{jn} [p_i(q_1, \dots, q_{3n})q_i]$. Plugging (2.2) into this profit function and maximizing it by choosing outputs simultaneously, i.e., $\partial \Pi_j / \partial q_i = 0$ yields the Cournot equilibrium quantity for each brand $q^{NM} = (1 + \mu) / [n(6 + 4\mu)]$. Plug q^{NM} into (2.2), one can get the equilibrium price for each brand $p^{NM} = (3 + \mu) / (6 + 4\mu)$.

Each firm realizes the same profit $\Pi^{NM} = np^{NM}q^{NM} = \frac{(1+\mu)(3+\mu)}{(6+4\mu)^2}$.

Following the utility function (2.1), the pre-merger equilibrium social welfare is $SW^{NM} = U^{NM} = \sum_{i=1}^{3n} q_i - \frac{3n}{2(1+\mu)} \left[\sum_{i=1}^{3n} q_i^2 + \frac{\mu}{3n} \left(\sum_{i=1}^{3n} q_i \right)^2 \right] = \frac{3(1+\mu)(9+5\mu)}{2(6+4\mu)^2}$.

Combining terms yields the result in the lemma. ■

Proof of Lemma 5. When the divestiture to a competitor is exogenous, at the stage (II) of the timing line, the antitrust authority approves the merger as long as the post-merger social welfare is not smaller than the pre-merger one, i.e. $U(k) + X \geq U^{NM}$. Rewriting this condition yields $X \geq U^{NM} - U(k)$, which is result of Lemma 5. ■

Proof of Proposition 4. Based on the more general gross profit function 2.3, the two post-merger firms' profits are

$$\begin{aligned}\Pi_m &= \sum_{i=1}^k [p_i(q_1, \dots, q_{3n})q_i] + X, \\ \Pi_d &= \sum_{i=(k+1)}^{3n} [p_i(q_1, \dots, q_{3n})q_i],\end{aligned}$$

where m indicates the merged entity, d indicates the competitor which gets the divestiture, i.e., firm 3. Using same procedure in Proof of Lemma 4, one can get the equilibrium quantities in the post-merger market.

$$\begin{aligned}q_m &= \frac{(1 + \mu) [3n(2 + \mu) - k\mu]}{3k\mu^2(3n - k) + 36n^2(1 + \mu)}, \\ q_d &= \frac{(1 + \mu)(6n + m\mu)}{3k\mu^2(3n - k) + 36n^2(1 + \mu)}.\end{aligned}$$

Plugging these two values into inverse demand function (2.2), the gross consumer surplus function (2.1) and the firms' profit functions showed above, at the end, we

can get

$$X_{\Pi}^*(k) = \frac{1+\mu}{18} \left[\frac{9(3+\mu)}{(3+2\mu)^2} - \frac{2k(3n+k\mu)(k\mu-3n(2+\mu))^2}{(k^2\mu^2-3kn\mu^2-12n^2(1+\mu))^2} \right],$$

$$X_U^*(k) = \frac{1}{72}(1+\mu) \left(\frac{27(9+5\mu)}{(3+2\mu)^2} - (4(8k^4\mu^3-48k^3n\mu^3+972n^4(1+\mu)+27kn^3\mu(8+19\mu)+9k^2n^2\mu(-8+\mu(-19+8\mu))))/(k^2\mu^2-3kn\mu^2-12n^2(1+\mu))^2 \right).$$

As $\partial X_{\Pi}^*(k)/\partial k < 0$, $\partial X_U^*(k)/\partial k < 0$ when $k \in (n, \frac{3}{2}n]$ and $\partial X_U^*(k)/\partial k > 0$ when $k \in [\frac{3}{2}n, 2n]$, the curve $X_{\Pi}^*(k)$ and the curve $X_U^*(k)$ cross at most twice when $k \in (n, 2n]$. We can avoid solving the maximization problem in a standard way, and only compare the values of $X_{\Pi}^*(k)$ and $X_U^*(k)$ at three crucial points, $k = n$, $k = \frac{3}{2}n$ and $k = 2n$. Moreover, we can split the proof into 3 cases according to the final results of mergers.

Case 1 When the results are either full merger or no merger.

According to Figure 2.2, one can get

$$\begin{aligned} X_U^*(n) &< X_{\Pi}^*(n) \\ X_U^*\left(\frac{3}{2}n\right) &< X_{\Pi}^*\left(\frac{3}{2}n\right), \\ X_U^*(2n) &\leq X_{\Pi}^*(2n). \end{aligned}$$

These three conditions cannot hold simultaneously because of the utility function we use and the conditions on the parameters, i.e., $\mu > 0$, $n \geq 2$ and $k \in (n, 2n]$.

Case 2 When the merger with remedies is feasible but the range of feasible k is smaller than $[\frac{3}{2}n, 2n]$.

Originally there are two subcases showed in Figure 2.3, in the main text of the paper we discuss them and reduce them into one case showed in Figure 2.5(a). So based on the more strict range of k , we have

$$\begin{aligned} X_U^*\left(\frac{3}{2}n\right) &< X_{\Pi}^*\left(\frac{3}{2}n\right), \\ X_U^*(2n) &> X_{\Pi}^*(2n). \end{aligned}$$

These two inequalities hold simultaneously as long as $\mu < \mu_1 \equiv (7 + \sqrt{97})/2$,

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meanwhile by $X_U^*(k) = X_\Pi^*(k)$, we can get the benchmark

$$\tilde{k} = \frac{3n}{2\mu(72 + 51\mu - \mu^2)} \times \frac{(\sqrt{5184 + 17280\mu + 19152\mu^2 + 8352\mu^3 + 1065\mu^4 - 54\mu^5 + \mu^6} - (72 + 24\mu - 19\mu^2 + \mu^3))}{(72 + 24\mu - 19\mu^2 + \mu^3)}.$$

Case 3 When the merger with remedies is feasible and the range of feasible k is $[\frac{3}{2}n, 2n]$.

Similarly with Case 2, using the reduced case showed in Figure 2.5(b), we have

$$\begin{aligned} X_U^*\left(\frac{3}{2}n\right) &\geq X_\Pi^*\left(\frac{3}{2}n\right), \\ X_U^*(2n) &> X_\Pi^*(2n). \end{aligned}$$

These two inequalities hold simultaneously as long as $\mu > \mu_1$.

Summarizing Case 1-3, one can get Proposition 4. ■

Proof of Lemma 6. When there are 4 pre-merger firms, the equilibrium pre-merger outcomes are:

$$\begin{aligned} q^{NM} &= \frac{1 + \mu}{n(8 + 5\mu)} \\ p^{NM} &= \frac{4 + \mu}{8 + 5\mu} \\ \Pi^{NM} &= \frac{(1 + \mu)(4 + \mu)}{(8 + 5\mu)^2} \\ U^{NM} &= \frac{12(1 + \mu)(2 + \mu)}{(8 + 5\mu)^2} \end{aligned}$$

When only one competitor gets the divestiture from the merged entity, then

the equilibrium outcomes are:

$$\begin{aligned}
q_1^m &= \frac{(1+\mu)(8+\mu)(8n-k\mu+3n\mu)}{A} \\
q_1^d &= \frac{(1+\mu)(8+\mu)(8n+k\mu)}{A} \\
q_1^c &= \frac{(1+\mu)(8+\mu)(8n-k\mu+3n\mu)}{nA} \\
\Pi_1^k &= \frac{k(1+\mu)(8+\mu)^2(4n+k\mu)(k\mu-n(8+3\mu))^2}{A^2}
\end{aligned}$$

where $A = -4k^2\mu^2(6+\mu) + 12kn\mu^2(6+\mu) + 8n^2(64+\mu(64+9\mu))$, q_1^d indicates the quantity produced by the competitor which gets the divestiture, and q_1^c indicates the quantity produced by the competitor which does not get.

When there are two competitor get the same divestitures from the merged entity, then the equilibrium outcomes are:

$$\begin{aligned}
q_2^m &= \frac{(1+\mu)(4n(4+\mu)-k\mu)}{2C} \\
q_2^d &= \frac{(1+\mu)(8n+k\mu)}{C}
\end{aligned}$$

$$\begin{aligned}
\Pi_2^k &= (k^2\mu(-1+\mu(-3+2(-1+8n)\mu)) - 16n^2(-4+\mu(-9-5\mu+8n(4+3\mu))) + \\
&\quad 16kn(1+\mu(3+\mu(3+\mu-2n(1+2\mu)))))/(2(1+\mu)C)
\end{aligned}$$

$\partial\Pi_1^k/\partial k > 0$ and $\partial\Pi_2^k/\partial k > 0$, so using the same method as before, we avoid solving the general inequality, but only compare their values at $k = n$ and $k = 2n$. Solving the pair of inequalities $\Pi_1^n \geq \Pi_2^n$ and $\Pi_1^{2n} \geq \Pi_2^{2n}$, we have $\mu \geq \bar{\mu}(n)$. ■

CHAPTER 2

Chapter 3

Asymmetric price adjustments: A supply side approach

This chapter is based on Antoniou, Fiocco and Guo (2015).

3.1 Introduction

A common observation in several markets is that retail prices react asymmetrically over time in response to changes in the input prices. In particular, if the input price tends to increase, the price for the final commodity reacts immediately. However, if the input price falls, the adjustment of the retail price is slower. A well-known example that corroborates this observation is the gasoline market.¹

The economic literature provides systematic empirical support for the phenomenon of asymmetric price adjustments, which is also known as rockets and feathers (e.g., Asplund et al. 2000; Bacon 1991; Blair and Rezek 2008; Borenstein et al. 1997; Chen et al. 2008; Deltas 2008; Green et al. 2010; Hannan and Berger 1991; Peltzman 2000; Valadkhani 2013; Verlinda 2008). Peltzman (2000, p. 466) emphasizes that “output prices tend to respond faster to input increases than to decreases. This tendency is found in more than two of every three markets examined.”

Asymmetric price adjustments have been repeatedly associated with the collu-

¹Other examples can be found in the coffee, corn and banking industries.

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sive behavior of firms. For instance, gasoline markets can be inclined to collusion since outputs and prices are easily observable by everyone. However, as Peltzman (2000) points out, the pattern of rockets and feathers is equally likely to be found in concentrated and atomistic markets. Recently, a relevant strand of literature has focused on the idea that consumers are imperfectly informed about market prices and a fraction of them face positive search costs. Prices respond asymmetrically since consumers cannot observe current production costs and their demand is sensitive to previous cost realizations.²

In this chapter we attempt to shed new light on asymmetric price adjustments in a standard competitive environment where firms provide a homogeneous good and compete in prices, abstracting from market imperfections such as collusion and limited information. The traditional economic theory suggests that firms earn zero profits and prices react symmetrically to cost shocks. Focusing on the supply side, we show that the nature of this result changes drastically if the opportunity of profitable storing is allowed.

A motivating example for our setting is the well-known shock that affected the US gasoline market in 2005 due to the hurricanes Katrina and Rita. According to the detailed investigation by the Federal Trade Commission (FTC), gas stations were selling gasoline in their tanks at significantly higher prices than actual costs and some of them earned substantial profits. The FTC found no evidence of collusion and concluded that the conduct of firms in response to the supply shocks caused by the hurricanes was consistent with competition (see FTC 2006).

We develop a two-period model where two firms sell a homogeneous good and engage in repeated Bertrand-Edgeworth competition by simultaneously setting prices and then ordering the desired quantities from their provider. A shock occurs in the economy, which makes the first period input (wholesale) costs diverge from the second period costs. In each period a firm can order a quantity up to a level that enables it to cover the whole market. Even though the possibility of price undercutting could drive prices to marginal costs, we find as a unique prediction of the game that a storage capacity leads to a prompt increase in prices above marginal costs when firms anticipate that the future input costs will be higher than the current costs. This is the case when storing for the next period is profitable,

²We refer to Section 3.2 for a review of the relevant literature.

3.1. INTRODUCTION

namely, when the discount factor is relatively high. The unique equilibrium price reflects the next period marginal cost, weighted by the discount factor.

The rationale behind this result is that profitable storing induces a firm to fill its depository, irrespective of what the rival does. A firm that prices at the discounted future input cost is indifferent between selling today or tomorrow and can store the purchased quantity if the rival undercuts its price and serves the market today. When input costs are expected to increase tomorrow, despite the scope for price undercutting the firms can coordinate on higher current prices than marginal costs. As a result, competition is relaxed and firms make positive profits.

It is worth emphasizing that a firm's commitment to increase its price in anticipation of higher input costs is credible as long as storing is profitable. When future discounting is relatively low and storing is unprofitable, the firms' incentives for price undercutting drive the price to the current marginal cost and the standard Bertrand outcome is restored. Consequently, prices adjust only after an increase in the input costs materializes, and the firms make zero profits.

In the same vein, when a shock is expected to decrease the input costs, storing for the next period is unprofitable and it does not serve as a commitment device. A price higher than marginal costs would drive a firm out of the market, while a price below marginal costs would entail losses. The firms are trapped in the Bertrand paradox and adjust their prices only after a cost change materializes, which yields zero profits. The opportunity of profitable storing implies that the immediate price adjustment to an input cost shock is more pronounced when the shock is positive than when it is negative. Hence, our results provide theoretical support for the phenomenon of rockets and feathers.

The driving force of our results persists in different alternative scenarios. For instance, in the baseline model we assume that the input supply is perfectly elastic and the firms cannot affect the input costs. However, in practice, input costs may also depend on the firms' demand. In a setting where input costs partially change already in the first period since the firms' higher than usual demand can only be covered at the new input cost, we find that our qualitative results remain unaffected. Storing drives asymmetric pricing even under alternative market structures, such as monopoly or Cournot competition.³ Therefore, our results provide

³We refer to Section 3.7 for a discussion on the robustness of our results.

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new insights into the phenomenon of asymmetric pricing which lend themselves to a validation from the empirical or experimental literature.

3.2 Related literature

The phenomenon of asymmetric price adjustments has been explored in the economic literature which provides alternative explanations. Using panel data on US sales volume and prices of gasoline, Borenstein and Shepard (1996) find evidence that the gasoline market is characterized by asymmetric price patterns and the firms' behavior is consistent with tacit collusion. A more recent strand of literature focuses on competitive environments, where consumers cannot perfectly observe market prices and search is costly. The main contributions differ in the driving force of asymmetric price adjustments and in the empirical predictions. Tappata (2009) considers a non-sequential search model with symmetric learning, while Yang and Ye (2008) provide an explanation for asymmetric pricing based on asymmetric learning by consumers. Arguing that previous work is not able to capture the specific patterns of price adjustments and of consumer search observed in retail gasoline markets, Lewis (2011) develops a search model which assumes that consumers' price expectations are based on prices observed during previous purchases. Cabral and Fishman (2012) investigate asymmetric price adjustments in a model where agents are inattentive to new information most of the time and only update their information at pre-specified intervals. As discussed in the introduction, our paper attempts to provide novel insights into the well-established phenomenon of asymmetric pricing, focusing on the supply side in a standard model that abstracts from market imperfections, such as collusion or limited information, and from behavioral aspects regarding the consumers.

Our analysis is also related to the literature on the role of inventories in the decisions of a firm. Particular attention has been devoted to the importance of inventory adjustments as a means to smooth the effects of shocks over time (e.g., Amihud and Mendelson 1983; Borenstein and Shepard 2002; Reagan 1982; Reagan and Weitzman 1982). In this paper, we emphasize the role of inventories as a driver of the asymmetric price response to input cost shocks.

The rest of the chapter is organized as follows. Section 3.3 describes the retail

3.3. THE US RETAIL GASOLINE MARKET

gasoline market in the US, whose main features are in line with our setting. Section 3.4 sets out the formal model. Section 3.5 derives the main results. Section 3.6 extends our model. Section 3.7 discusses the robustness of our results. Section 3.8 concludes. All formal proofs are collected in the Appendix.

3.3 The US retail gasoline market

Although we do not aim at explicitly modeling the retail gasoline market, our setting reflects some relevant features of this market. In the US an estimated 80% of fuel is currently sold by relatively small retail outlets and their dominance continues to grow. The majority of these firms are single-store operators – more than 70,000 stores across the country. Half of the retail outlets sell fuel under the brand of a refining company, but virtually all of them are operated by independent entrepreneurs. The remaining half sell unbranded fuel, which is purchased on the open market or via unbranded contracts with a refiner or distributor. A station usually obtains gasoline either directly at a terminal price known as the “rack” price or through an intermediate supplier called a “jobber” which typically charges a competitive margin over the rack price.⁴

Retail gasoline prices are publicly observable and in some states (e.g., New Jersey and Wisconsin) consumer protection laws require that posted gasoline prices remain in effect at least for a given period, generally 24 hours. Since gasoline evaporates rather quickly, carrying large quantities is suboptimal. Moreover, the size of tanks in gas stations is limited by physical constraints. The report of the economist Keith Leffler (2007, p. 33), which investigates the factors that influence regional gas prices throughout the state of Washington, states that “the inventory philosophy of producers is ‘just in time’ to have adequate supplies to meet expected demand. Only two to five days of finished product is available to bridge short-term supply interruptions.”

When setting the prices and ordering the quantities from their providers, the retailers generally face the rack price (plus a competitive distribution margin) as

⁴The interested reader is referred to the NACS Retail Fuels Report of the Association for Convenience and Fuel Retailing available at www.nacsonline.com/YourBusiness/FuelsReports/Pages/default.aspx.

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a marginal cost. If unexpected events occur which affect the import or refining stage (say, a conflict in an oil-producing country or a hurricane), rack prices may increase immediately and, more relevantly, they are expected to rise even more in the near future due to possible supply shortages. In particular, as described in the NACS Retail Fuels Report of the Association for Convenience and Fuel Retailing (2013, p. 63), “when disruptions occur, retailers [...] are susceptible to changes in product availability and volatile wholesale prices. Branded fuel retailers may incur price increases and be put on volume allocations. Meanwhile, unbranded retailers may experience more dramatic wholesale price increases, since they must compete for limited supply on the spot market, or be denied access to supplies completely.”

3.4 The model

Setting We consider two symmetric firms $i = 1, 2$ that provide a homogeneous good and engage in repeated Bertrand-Edgeworth competition by simultaneously deciding on their prices and then on their output levels, which is known in the literature as production to order (e.g., Chowdhury 2005; Dixon 1984; Maskin 1986). As discussed in section 7, our qualitative results go through when prices and quantities are set simultaneously.⁵ In each period $\tau = 1, 2$, firm i sets a price $p_{\tau i}$ for the good and then orders a quantity $q_{\tau i}$ from its provider. We denote by $q_{\tau i}^m$ the quantity that firm i places on the market in period τ . Since we aim at analyzing short-term events, we assume that market demand is inelastic and in each period consumers purchase a quantity $d > 0$ irrespective of the price level.⁶ Following the relevant literature (see Chowdhury 2005 and the references cited

⁵We refer to Allen and Hellwig (1986), Dasgupta and Maskin (1986), Dixon (1984) and Maskin (1986) for an analysis of equilibrium existence in Bertrand-Edgeworth models. More recently, Chowdhury (2009) investigates a model of Bertrand competition in the presence of non-rigid capacity constraints.

⁶Inelastic demand seems to be a reasonable assumption in the gasoline retail market, where consumer demand is largely unresponsive to changes in prices at least in the short run. In section 7 we argue that our qualitative results go through with more general demand functions.

3.4. THE MODEL

therein), the residual demand for firm i is given by

$$R_{\tau i}(p_{\tau i}, p_{\tau j}, q_{\tau j}^m) = \begin{cases} d - q_{\tau j}^m & \text{if } p_{\tau i} > p_{\tau j} \\ \max\left\{\frac{d}{2}, d - q_{\tau j}^m\right\} & \text{if } p_{\tau i} = p_{\tau j} \\ d & \text{if } p_{\tau i} < p_{\tau j}. \end{cases} \quad (3.1)$$

The residual demand in (3.1) is distributed according to the efficient rationing rule. As long as the demand is inelastic, this formulation captures any combined rationing rule, including the proportional rationing rule (e.g., Tasnádi 1999). The second line of equation (3.1) identifies the tie-breaking rule that is used, among others, in Davidson and Deneckere (1986) and Kreps and Scheinkman (1983). This formulation exhibits the attractive feature that it allows for the spillover of the uncovered residual demand from one firm to another.⁷

The quantity $q_{\tau i}$ that firm i orders in each period cannot exceed d , which represents the firm's storage capacity.⁸ This assumption is reasonable in markets where storing large quantities is unfeasible. For instance, as argued in section 3, gasoline evaporates quite quickly and the size of tanks in gas stations is limited by physical constraints. In section 7 we show that our qualitative results carry over with alternative storage capacities. Notably, a storage capacity equal to d allows each firm to serve the whole market, and the possibility of price undercutting could drive prices to marginal costs.

Each period τ firm i may store (a part of) the ordered quantity $q_{\tau i}$ for the next period. Let $q_{\tau i}^r$ be the quantity that firm i stores in period τ for the period $\tau + 1$, namely, firm i 's reserves. The firms incur a constant cost c_τ per unit of input (e.g., the rack price for gasoline) in period τ .

Firm i 's profits in period τ are given by

$$\pi_{\tau i} = p_{\tau i} \min(q_{\tau i}^m, R_{\tau i}(p_{\tau i}, p_{\tau j}, q_{\tau j}^m)) - c_\tau q_{\tau i}, \quad \tau, i = 1, 2,$$

which represents the difference between total revenues and total costs. Total revenues depend on the quantity sold on the market. Since we allow for voluntary

⁷Our results carry over with alternative tie-breaking rules, such as $R_{\tau i} = d \frac{q_{\tau i}^m}{q_{\tau i}^m + q_{\tau j}^m}$ (for $q_{\tau i}^m + q_{\tau j}^m > 0$, this tie-breaking rule becomes $R_{\tau i} = \frac{d}{2}$).

⁸We assume that storage is costless. Introducing a positive cost of storage does not alter our qualitative results.

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trading, this quantity is the minimum between the quantity that the firm puts on the market and the firm's residual demand in (3.1).⁹ The firm's total costs depend on the quantity ordered.

Firm i 's aggregate profits can be written as

$$\pi_i = \pi_{1i} + \delta\pi_{2i},$$

where $\delta \in (0, 1]$ is the discount factor on the second period.

Input cost shock As discussed in the introduction, our purpose is to investigate a situation where a shock occurs in the input market which makes the current input costs diverge from the future costs. If the shock is positive, input costs tend to increase, i.e., $c_2 > c_1$. This is typically the case after extreme weather phenomena or the exacerbation of political instability in an oil-producing country, which can lead to supply disruptions. If the shock is negative, such as the sudden end of a conflict in an oil-producing country or the announcement of the US Department of Energy that the strategic oil inventories have increased, then input costs tend to decrease, i.e., $c_2 < c_1$. For the sake of simplicity, we assume that input costs vary in a deterministic way, but our results carry over even with cost uncertainty as long as the firms expect that future costs will depart from current costs.

In the baseline model we suppose that the input supply is perfectly elastic in every period. Since in practice retailers may affect input prices through their demand, in section 6 we consider a situation where input costs partially change already in the first period since the retailers' higher than usual demand can only be satisfied at the new input cost.

Timing and equilibrium concept The timing of the model unfolds as follows.

First period

- (I) Cost c_1 is realized.
- (II) The firms simultaneously set their prices.

⁹Nothing substantial would change if the firms must fully cover the consumer demand.

3.5. MAIN RESULTS

(III) The firms simultaneously order the quantities that are sold on the market or stored in the depository for the next period.

Second period

(IV) Cost c_2 is realized.

(V) The first period competition stages (II) and (III) are repeated.

The equilibrium concept we adopt is the Subgame Perfect Nash Equilibrium (SPNE).¹⁰ Moving backwards, we first derive the equilibrium prices and quantities in the second period. Afterwards, we determine the first period outcome of the game and derive the corresponding equilibrium prices and quantities.

3.5 Main results

3.5.1 Second period equilibrium

The following lemma characterizes the equilibrium prices and quantities in the second period.

Lemma 7 *A. If $\sum_{i=1}^2 q_{1i}^r \leq d$, the outcome $(p_{2i}^*, q_{2i}^{m*}, q_{2i}^{r*})$ constitutes an equilibrium of the second period continuation game if and only if $p_{2i}^* = c_2$, $\sum_{i=1}^2 q_{2i}^{m*} \leq d$ and $q_{2i}^{r*} = 0$, $i = 1, 2$.*

B. If $\sum_{i=1}^2 q_{1i}^r > d$, the outcome $(p_{2i}^, q_{2i}^{m*}, q_{2i}^{r*})$ constitutes an equilibrium of the second period continuation game if and only if $p_{2i}^* \in [\underline{p}_2^*, \bar{p}_2^*] \subseteq [0, c_2]$, $\sum_{i=1}^2 q_{2i}^{m*} = d$ and $q_{2i}^{r*} = \max\{0, q_{1i}^r - q_{2i}^{m*}\}$, $i = 1, 2$.*

Lemma 7A indicates that, if the total amount of reserves from the first period does not exceed the demand d , the equilibrium price in the second period reflects the current marginal cost c_2 . This holds true even though the cost of reserves was incurred in the first period and it is therefore zero in the second period. A price higher than the marginal cost clearly drives a firm out of the market. No firm has an incentive to set a price below the marginal cost, since it cannot undercut the

¹⁰In line with the main literature we allow for mixed strategies but look for SPNE without mixing on the equilibrium path.

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rival's price and profitably sell more than its reserves. Moreover, since we allow for voluntary trading, in equilibrium a part of the market may remain uncovered, yet the reserves are fully exhausted.

As Lemma 7B reveals, things are different when the aggregate reserves are greater than the demand. Since the market cannot absorb all the reserves and their cost was sunk in the first period, a price war takes place between the firms as they try to sell their reserves. Following Levitan and Shubik (1972) and Osborne and Pitchik (1986), there exists a (generally unique) mixed strategy equilibrium where firms randomize in prices within the interval $[p_2^*, \bar{p}_2^*] \subseteq [0, c_2]$. Any price above c_2 cannot be set with positive probability, since the standard undercutting rationale applies. Contrary to the case where the total amount of reserves does not exceed the demand, choosing with probability 1 a price equal to the marginal cost cannot be sustained as an equilibrium, since each firm has an incentive to undercut the rival and sell off all its reserves. The lower bound of the price interval crucially depends on the amount of reserves. If either firm does not carry full reserves, i.e., $\sum_{i=1}^2 q_{1i}^r \in (d, 2d)$, the minimum price is strictly above zero since (at least) the firm with lower reserves cannot serve the whole market, which mitigates the incentives to undercut. Only if both firms carry full reserves, i.e., $q_{1i}^r = d$, $i = 1, 2$, can each firm undercut the rival and serve the whole market, which drives the price to zero. The market demand is always satisfied through the reserves.

An implication of Lemma 7, which is useful throughout the rest of the analysis, is that the second period equilibrium price can never exceed the current input cost c_2 , irrespective of what occurred in the first period.

3.5.2 No shock

For illustrative purposes we first consider the benchmark case where no shock occurs, i.e., $c_1 = c_2 \equiv c$. This translates into a dynamic version of the one-period game described in Chowdhury (2005) where we introduce the storing option.

The following remark summarizes the equilibrium of the game in the absence of a shock.

Remark 2 *Suppose $c_1 = c_2 \equiv c$. Then, the outcome $(p_{\tau i}^*, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{\tau i}^* = c$ and $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$, $\tau, i = 1, 2$. If $\delta < 1$, then $q_{\tau i}^{r*} = 0$,*

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$\tau, i = 1, 2$. If $\delta = 1$, then $\sum_{i=1}^2 q_{1i}^{r*} \leq d$ and $q_{2i}^{r*} = 0$, $i = 1, 2$.

The opportunity of storing some quantity for the next period does not alter the outcome of the static game. The firms set a price equal to the marginal cost in each period and earn zero profits. If $\delta < 1$, storing is clearly profit detrimental, since the marginal cost c is higher than the second period discounted price (which is bounded above at δc , according to Lemma 7). If $\delta = 1$, storing is at best not harmful and the firms cannot improve their profits. Therefore, in equilibrium the firms are indifferent to storing or not provided that the total amount of reserves does not exceed the demand. Otherwise, the second period price would fall below c and storing would be detrimental.

3.5.3 Positive shock

For the sake of convenience, we split our analysis according to the direction of the shock in the input market. We first investigate the case of a positive shock where input costs tend to increase, i.e., $c_2 > c_1$. Intuitively, a positive shock creates an incentive to purchase at a cost c_1 a quantity that is higher than usual. We know from Lemma 7 that, if the aggregate stored quantity from the first period does not exceed the demand, the second period price will be equal to the new marginal cost c_2 . This gives the firms the opportunity to sell at a positive margin.

The following proposition describes the equilibrium of the game in the presence of a positive shock.

Proposition 5 *Suppose $c_2 > c_1$.*

A. *If $\delta \geq \frac{c_1}{c_2}$, the outcome $(p_{\tau i}^*, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{1i}^* = \delta p_{2i}^* = \delta c_2$, $\sum_{i=1}^2 q_{\tau i}^{m*} = d$, $q_{1i}^{r*} = d - q_{1i}^{m*}$ and $q_{2i}^{r*} = 0$, $\tau, i = 1, 2$.*

B. *If $\delta < \frac{c_1}{c_2}$, the outcome $(p_{\tau i}^*, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{\tau i}^* = c_\tau$, $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$ and $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$.*

Proposition 5A considers the case where the discount factor δ is relatively high so that purchasing one unit of the commodity at c_1 in the first period and selling it at c_2 in the second period is profitable. Anticipating higher future input costs, the firms immediately adjust their prices at the discounted second period input cost δc_2 . In order to substantiate the intuition behind this result as provided

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in the introduction, it is important to realize that for $\delta \geq \frac{c_1}{c_2}$ each firm has an incentive to purchase a quantity d in the first period, which can be partially stored and profitably sold in the second period. It follows from Lemma 7 that, if the aggregate reserves do not exceed the demand, a firm that adjusts its price at δc_2 is indifferent between serving the market today or tomorrow. Therefore, it can credibly commit to purchase d even if the rival undercuts its price. In particular, if the undercutting firm prefers to (partially) serve the market today, the non-deviating firm can store (a portion of) d and sell it tomorrow at c_2 . Any deviation above δc_2 is unprofitable as long as the firm conjectures that the rival will cover the whole market.

As described in Remark 2, in the absence of a shock each firm cannot credibly commit not to be aggressive vis-à-vis the rival, and the standard Bertrand rationale applies. When input costs are expected to increase tomorrow, profitable storage acts as a commitment device to increase prices already today, which relaxes competition. The firms can coordinate to increase prices above marginal costs and earn positive profits. Notably, Proposition 5A shows that the price at the discounted second period input cost is the unique equilibrium of the game.¹¹ Although the market can be split between firms in several manners (the symmetric equilibrium $q_{\tau i}^{m*} = \frac{d}{2}$, $\tau, i = 1, 2$, is only one possibility among others), the market is fully covered in both periods because each firm orders and sells d .

Since we aim at analyzing short-term events, we expect that the discount factor will be relatively high and the outcome of Proposition 5A is the most relevant for our purposes. Proposition 5B describes what happens if the firm's future discounting is low enough, i.e., $\delta < \frac{c_1}{c_2}$. The rationale for this result is immediate in light of our previous discussion. Since storing is not profitable and cannot be used as a commitment device to relax competition, the firms are trapped in the Bertrand paradox and set their prices at the current marginal costs, which yield zero profits.

¹¹We refer to the proof of Proposition 1 in the Appendix for technical details.

3.5.4 Negative shock

We now turn to the case of a negative shock where input costs tend to decrease, i.e., $c_2 < c_1$. The following proposition summarizes the main results.

Proposition 6 *Suppose $c_2 < c_1$. Then, the outcome $(p_{\tau i}^*, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{\tau i}^* = c_\tau$, $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$ and $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$.*

Proposition 6 replicates the outcome in Proposition 5B. When a shock is expected to reduce the input costs, storing is clearly unprofitable and firms cannot coordinate on prices higher than marginal costs. Moreover, any price below the current costs would entail non-positive profits. As a consequence, the price in each period reflects the current marginal cost and the standard Bertrand rationale applies.

It is worth noting that in our model the role of storing depends on the discount factor but it can be also viewed as a function of the magnitude of the shock in the input market for a given discount. An alternative interpretation of our results is that, if the magnitude of the shock is large enough (i.e., if c_2 is sufficiently higher than c_1), storing is profitable and the firms adjust their prices to the cost shock faster than when the shock is relatively small or even negative. The driving force of our results is the opportunity of profitable storing and, as it emerges from sections 3.6 and 3.7, the model is robust to perturbations of the initial assumptions in different directions, as long as storing is relevant.

3.5.5 Empirical implications

We are now in a position to relate our results to the empirical predictions. In order to derive the price-cost pass-through rates over time, we introduce a pre-shock period, called period 0, where the input cost is the same as in the first period, i.e., $c_0 = c_1$.¹² Moreover, we assume that in period 0 the price reflects the current marginal cost, $p_0 = c_0$.¹³ Using the results in Propositions 5 and 6, the

¹²The results remain qualitatively unaffected if the input shock also alters the cost already in the first period, i.e., $c_0 \neq c_1$.

¹³In other terms, before the shock we are in the long-run equilibrium. This is a reasonable assumption when the future shock is unexpected, so that the firms cannot react in period 0. Any other price-cost relationship in period 0 that differs from marginal cost pricing does not alter our qualitative conclusions.

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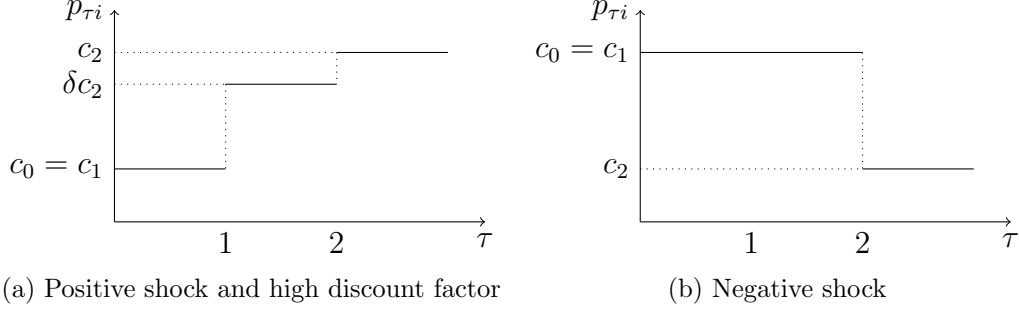


Figure 3.1: Price adjustments

percentage variations in prices following a shock are

$$\hat{\beta}_0^+ = \frac{\delta c_2 - c_1}{c_1}, \hat{\beta}_1^+ = \frac{1 - \delta}{\delta}, \hat{\beta}_0^- = 0, \text{ and } \hat{\beta}_1^- = \frac{c_1 - c_2}{c_1}, \quad (3.2)$$

where $\hat{\beta}_0^+$ and $\hat{\beta}_1^+$ respectively denote the percentage variations in prices between periods 0 and 1 and between periods 1 and 2 due to a positive input shock (for $\delta \geq \frac{c_1}{c_2}$). The interpretation of $\hat{\beta}_0^-$ and $\hat{\beta}_1^-$ follows similarly in case of a negative shock. A comparison between $\hat{\beta}_0^+$ and $\hat{\beta}_0^-$ immediately reveals that $\hat{\beta}_0^+ > \hat{\beta}_0^-$ for $\delta > \frac{c_1}{c_2}$, namely, final prices rise faster when input costs increase than when they fall if storing is profitable. In particular, $\hat{\beta}_0^- = 0$ indicates an initial price stickiness with a negative shock. The speed of later adjustment is reversed, namely, $\hat{\beta}_1^+ < |\hat{\beta}_1^-|$. This is in line with the main empirical literature (e.g., Borestein et al. 1997; Chesnes 2012), which shows that retail prices initially react faster when the input shock is positive but the opposite occurs when the total adjustment is near completion.

It is also worth noting from (3.2) that, unless $\delta = 1$, the price adjustment in case of a positive shock unravels gradually. In particular, we have $\hat{\beta}_1^+ > \hat{\beta}_0^+$ if $\delta > (\frac{c_1}{c_2})^{\frac{1}{2}}$. Put differently, when the discount factor is relatively high, the relative increase in prices is more pronounced in the first than in the second period. This is consistent with the empirical evidence that the price-cost pass-through declines over time with a positive shock.

Our results are depicted for illustrative purposes in Figure 3.1, where panel (a) shows the price adjustment over time in the presence of a positive shock and panel

3.5. MAIN RESULTS

(b) indicates the price adjustment with a negative shock.

To investigate the empirical implications of our results, it is also helpful to translate them in terms of empirical models. Our predictions can be estimated via a dynamic model of the following form

$$\Delta p_\tau = \sum_{i=0}^{n^+} \beta_i^+ \Delta c_{\tau+k-i}^+ + \sum_{i=0}^{n^-} \beta_i^- \Delta c_{\tau+k-i}^- + \varepsilon_\tau. \quad (3.3)$$

Equation (3.3) reflects the idea that the spread in retail prices Δp_τ between periods $\tau - 1$ and τ depends on positive and negative cost changes $\Delta c_{\tau+k-i}^+$ and $\Delta c_{\tau+k-i}^-$ at possibly different rates β_i^+ and β_i^- , plus an error term ε_τ .¹⁴ The term $k \geq 0$ captures the impact of anticipated future cost changes on the current price change. For $k = 0$ the econometric model in (3.3) is fairly standard in the empirical literature (e.g., Borenstein et al. 1997; Chesnes 2012). Positive values of k indicate that an anticipated cost change between periods $\tau + k - 1$ and $\tau + k$ can affect the price change already k periods earlier. This is a key message of our paper for the empirical studies. The predictions of our model suggest that in markets with storing opportunities the anticipation of future cost changes is a relevant driver for asymmetric pricing.

Our aim is to derive the estimated β_i^+ and β_i^- in (3.3) that our model generates. The phenomenon of rockets and feathers occurs if $\beta_i^+ > \beta_i^-$ for at least one lag i . We first consider the case of a positive shock, $c_2 > c_1$, and a relatively high discount factor, $\delta \geq \frac{c_1}{c_2}$. Since in our stylized two-period model only the costs in the next period can be anticipated, i.e., $k = 1$, plugging our results into (3.3) and neglecting the error term ε_τ yields after some manipulation

$$p_1 - p_0 = \delta c_2 - c_1 = \beta_0^+(c_2 - c_1)$$

$$p_2 - p_1 = c_2 - \delta c_2 = \beta_1^+(c_2 - c_1).$$

This implies $\beta_0^+ = \frac{\delta c_2 - c_1}{c_2 - c_1}$ and $\beta_1^+ = \frac{c_2 - \delta c_2}{c_2 - c_1}$. When the shock is negative, we find

$$p_1 - p_0 = 0 = \beta_0^-(c_2 - c_1)$$

¹⁴Equation (3.3) may also include an error correction term that accounts for deviations from the long-run equilibrium. Neglecting this term does not affect our results qualitatively.

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$$p_2 - p_1 = c_2 - c_1 = \beta_1^-(c_2 - c_1),$$

which yields $\beta_0^- = 0$ and $\beta_1^- = 1$. The predictions of our model reveal the existence of asymmetric pricing. We find for $\delta > \frac{c_1}{c_2}$ that $\beta_0^+ > \beta_0^- = 0$, namely, the immediate price adjustment is larger with a positive shock than with a negative shock when storing is profitable, and the negative shock is associated with a price stickiness. The speed of later adjustment is reversed, $\beta_1^+ < \beta_1^-$. Moreover, we have $\sum_{i=0}^{n^+} \beta_i^+ = \sum_{i=0}^{n^-} \beta_i^-$, which is consistent with the empirical evidence that in most markets the wholesale and retail prices do not tend to diverge over time.

3.6 Endogenous input cost

The results derived so far are based on the assumption that in each period the input supply is perfectly elastic. Put differently, each firm could potentially order infinite quantities at the current input costs. In reality, however, the change in the firms' demand due to a shock may affect the input costs. To investigate this case, we now assume that in the first period the (common) provider can obtain a quantity up to d (which represents the 'historical' quantity, i.e., the quantity in the absence of a shock) at a cost c_1 , for instance, due to long-term contracts. If the provider wants to acquire larger quantities to serve the firms' demand, it must resort to other sources (say, the spot market) and pay the new input cost c_2 on the additional amount already in the first period. The provider's average cost function exhibits a kink at d , and the price charged by the provider now depends on the firms' demand for the input.

An endogenous input cost complicates the analysis, since it creates an interdependence between the firms' costs. Nonetheless, as this reflects economic realities to some extent, an investigation of such a case is warranted in order to check the robustness of the results presented in the previous section.

In light of this discussion, the average input cost in the first period is given by

$$\tilde{c}_1 = \frac{c_1 \min d, \sum_{i=1}^2 q_{1i} + c_2 \max 0, \sum_{i=1}^2 q_{1i} - d}{\sum_{i=1}^2 q_{1i}}. \quad (3.4)$$

We assume that the provider sets an input price equal to the average cost in

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(3.4) plus a fixed markup (normalized to zero). This input price rule captures in a simple but effective manner the idea that the firms' demand affects the input price, abstracting from the mode of competition in the upstream market. When the firms' demand does not exceed d , the provider does not need to purchase any quantity from additional sources and therefore the first period input cost is c_1 . If, however, the firms' demand is higher than d , the provider must acquire any additional quantity at c_2 , which increases (decreases) the average cost in (3.4) if $c_2 > (<) c_1$ and affects in the same direction the input cost incurred by the firms.

3.6.1 Positive shock

The following proposition considers the case of a positive shock.

Proposition 7 *Suppose $c_2 > c_1$.*

A. If $\delta \geq \frac{1}{4}(3 + \frac{c_1}{c_2})$, the outcome $(p_{\tau i}^, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{1i}^* = \delta p_{2i}^* = \delta c_2$, $\sum_{i=1}^2 q_{\tau i}^{m*} = d$, $q_{1i}^{r*} = d - q_{1i}^{m*}$ and $q_{2i}^{r*} = 0$, $\tau, i = 1, 2$.*

B. If $\frac{c_1}{c_2} \leq \delta < \frac{1}{4}(3 + \frac{c_1}{c_2})$, no equilibrium exists.

C. If $\delta < \frac{c_1}{c_2}$, the outcome $(p_{\tau i}^, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{\tau i}^* = c_\tau$, $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$ and $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$.*

Proposition 7A indicates that, if the discount factor is sufficiently high, i.e., $\delta \geq \frac{1}{4}(3 + \frac{c_1}{c_2})$, the equilibrium price in the first period equals the discounted second period marginal cost δc_2 and reaches c_2 in the second period, which ensures that each firm is indifferent to selling across the two periods. The critical value of the discount factor, $\frac{1}{4}(3 + \frac{c_1}{c_2})$, corresponds to the threshold above which each firm orders d in the first period and the demand is fully covered in each period. The intuition for this result falls across the same lines as in Proposition 5A. It is worth mentioning that the critical threshold of the discount factor is higher than in the baseline model, i.e., $\frac{1}{4}(3 + \frac{c_1}{c_2}) > \frac{c_1}{c_2}$. The idea is that now storing increases the firms' unit costs already in the first period, which strengthens the condition under which each firm finds it optimal to order d in the first period.

Another dimension introduced by an endogenous input cost is the indeterminacy for an intermediate range of values for the discount factor, i.e., $\frac{c_1}{c_2} \leq \delta < \frac{1}{4}(3 + \frac{c_1}{c_2})$. As Proposition 7B reveals, in this case no equilibrium exists (in pure

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or in mixed strategies). To fix ideas, consider the equilibrium prices described in Proposition 7A. At these prices, since for intermediate values of the discount factor storing is still profitable but to a lower extent than in the previous case, the quantity equilibrium involves orders lower than d in the first period. Following a price increase of the rival, the non-deviating firm still does not want to order d and serve the whole market. This implies that a firm can (infinitely) raise its price in the first period and serve the uncovered part of the market. This conclusion differs from the result in the baseline model, where each firm has an incentive to order d in the first period for $\delta \geq \frac{c_1}{c_2}$ irrespective of what the rival does, which prevents any profitable deviation. The reason is that storing now increases the firms' unit costs already in the first period, which makes storing less attractive.

Following a loose dynamic argument, as long as the first period prices are higher than δc_2 , each firm has an incentive to undercut the rival's price in order to sell in the first period. Moreover, any price below δc_2 cannot be supported as an equilibrium, since the non-deviating firm would prefer to sell in the next period while the rival could increase the price and sell profitably in the first period. Hence, for $\frac{c_1}{c_2} \leq \delta < \frac{1}{4}(3 + \frac{c_1}{c_2})$, there is no equilibrium in the price setting game and therefore no SPNE exists.¹⁵

Proposition 7C predicts that, if the discount factor is low enough, i.e., $\delta < \frac{c_1}{c_2}$, storing is unprofitable and no firm has an incentive to order any quantity for the next period irrespective of what the rival does, since this would result in a net loss. Therefore, prices adjust to the current input costs as in Proposition 5B and the standard Bertrand argument applies in each period of the game.

¹⁵The indeterminacy arises in our model mainly because of the inelastic demand. This problem can be removed if a choke price is introduced above which the demand is zero or alternatively if we allow for a negatively sloped demand function (which is not considered here for the sake of tractability). Following Dixon (1984) and Maskin (1986), in either case a mixed strategy equilibrium exists. Interestingly, the equilibrium involves a set of prices higher than δc_2 in the first period. No firm has an incentive to set a price lower than δc_2 since it could sell in the second period and obtain the same profits. However, it follows from the previous discussion that a firm recognizes that it can increase the price in the first period because the rival's inability to commit to order d implies that a part of the market will remain uncovered. This yields an upper bound of the price range at the monopoly price on the residual demand. Therefore, the price response to the input cost shock can be even more severe than with higher future discounting.

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3.6.2 Negative shock

The following proposition describes what happens in the case of a negative shock.

Proposition 8 *Suppose $c_2 < c_1$. Then, the outcome $(p_{\tau i}^*, q_{\tau i}^{m*}, q_{\tau i}^{r*})$ constitutes a SPNE if and only if $p_{\tau i}^* = c_\tau$, $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$ and $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$.*

Proposition 8 replicates the outcome of Proposition 6. As in the baseline model, storing is unprofitable since the first period cost \tilde{c}_1 is higher than the second period cost c_2 . However, deriving the equilibrium is now more demanding as \tilde{c}_1 might be lower than c_1 in equilibrium. This would be the case if the aggregate orders in the first period are higher than d . Things become more complicated since it is not straightforward to see whether price undercutting below c_1 in the first period is profitable or not. Indeed, it turns out to be unprofitable since the non-deviating firm does not order any positive quantity (which cannot be sold in the first period) and therefore the undercutting firm does not benefit from a reduction in the input costs. In equilibrium, the price is equal to c_1 in the first period and to c_2 in the second period. Since we allow for voluntary trading, a part of the demand may remain uncovered.

Notably, we can exclude the existence of other equilibria. In particular, prices above c_1 in the first period cannot be supported as an equilibrium because of the usual Bertrand argument. Any equilibrium cannot sustain prices below c_1 since a firm has an incentive to deviate upward in the first period and set a price above c_1 . An interesting feature of the quantity setting game following this deviation is that it does not exhibit any equilibrium in pure strategies. The firm with the price below c_1 strictly prefers to order either zero or d to any other strategy. However, this firm cannot order zero with probability 1 in equilibrium, since the rival would purchase d , which induces the firm to deviate by ordering a positive quantity as the input cost \tilde{c}_1 declines. Moreover, the firm cannot order d with probability 1 in equilibrium, otherwise the rival would purchase zero and the associated cost $\tilde{c}_1 = c_1$ would entail losses. The quantity setting game resembles a game of matching pennies, and it turns out that the firm with the price above c_1 sells some quantity at a positive margin while the firm with the price below c_1 mixes between ordering zero and d so that it earns zero (expected) profits and the market is fully covered.

3.7 Robustness

3.7.1 Mode of competition

In our model the firms set prices and then decide on quantities, which is known in the literature as production to order. The case in which prices and quantities are determined simultaneously also deserves some attention. The main technical problem identified in a simple static framework by Chowdhury (2005) is the nonexistence of pure strategy equilibria. Under some mild conditions (such as a finite price at which profits are maximized), Allen and Hellwig (1986) and Dasgupta and Maskin (1986) establish the general existence of an equilibrium in mixed strategies. Since in our framework the strategic role of profitable storage does not crucially depend on the observability of the rivals' prices, we expect that our results will carry over in this scenario, although the derivation of equilibria would be more cumbersome. The case of a negative shock does not add any element of interest to the analysis, since storing is unprofitable and the equilibrium of the static game persists.

It is also worth exploring whether the strategic role of storing as an explanation for asymmetric pricing emerges even in a monopolistic setting or under alternative competitive structures such as Cournot competition. Indeed, we can show that storing affects the pricing strategy of a monopolist in several possible manners. Similar results hold when firms compete in Cournot fashion.¹⁶ To make the problem interesting, consider a standard downward sloping demand function. When the shock is negative, storing is unprofitable and the monopoly price equalizes current marginal revenues and the current (constant) marginal costs in each period. When the shock is positive and storing is profitable, $\delta \geq \frac{c_1}{c_2}$, the monopolist's pricing strategy depends on the size of the storage capacity. If the capacity is so large that the firm can cover the demand in two periods, the price in the first period still equalizes current marginal revenues and current marginal costs, while the price in the second period equalizes the discounted marginal revenues and the first period marginal costs. This implies that in the first period the price adjustment follows the same pattern as with a negative shock, but the second period price adjustment

¹⁶All our claims can be proved formally. Computations are available upon request.

is smaller. When the storage capacity is tight, the monopolist faces a trade-off between selling the quantity in the first period or storing it for the second period. In this case the firm prefers to increase the price in the first period in order to reduce its current sales and store more output for the next period. Specifically, if the size of the storage capacity is very small (below a certain threshold level), the monopolist will also produce (or purchase from its distributor) in the second period and the level of prices in the two periods cannot be unambiguously ranked. Interestingly, the price may even decrease in the second period despite the increase in the input costs. If the capacity is relatively less stringent (above the threshold level), the monopolist will only produce (or purchase from its distributor) in the first period and it will prefer to sell more in the first period than in the second period (due to the discount factor). In line with the empirical evidence, the price adjustment in the first period turns out to be more pronounced than with a negative shock, while the opposite occurs in the second period.

3.7.2 Storage capacity

Throughout the analysis we assume that a firm's storage capacity is exogenous and equal to the market demand in each period. As argued in section 3.3, a capacity level equal to the demand in each period is a reasonable assumption, since each firm is able to undercut the rival and serve the whole market. Less interesting is the case in which the capacity is below d . In such a scenario, each firm is a monopolist on the residual demand, which creates the incentive to raise prices above marginal costs even in the absence of a shock. Following Levitan and Shubik (1972) and Osborne and Pitchik (1986), it can be shown that there exist mixed strategy equilibria involving prices above marginal costs. A positive shock that entails higher future costs still creates opportunities for profitable storing and, in line with our results, prices will increase. In such a case, however, the analysis would be less transparent.

If the firm's capacity is larger than d , the analysis becomes more cumbersome. In a two-period game, the firms may not be able to sell their initial orders. Our conclusions remain valid but the incentive to immediately increase prices with a positive shock is mitigated. Notably, an increase in the number of periods fully

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restores our results.

Related to this discussion is the question of the robustness of our results to an increase in the number of periods. If the game is long enough so that firms are able to sell all quantities at a certain future point in time, no price war occurs between firms to empty their depositories and the price randomization in Lemma 7B no longer emerges. In this case, if a positive shock occurs the price adjustment takes place gradually, provided that the discounted profits are equal across periods.

3.7.3 Input costs

In our setting input costs move in a deterministic way. As argued in section 3.4, nothing would change substantially if we assume that costs follow a stochastic process, provided that future costs are expected to depart from the current ones. One may wonder why in our model no trader can exploit arbitrage opportunities arising from expected cost increases in the future. For instance, in the gasoline market intermediaries could store some quantities and increase the current prices charged to retailers. Notably, even in this case the mechanism described in our analysis goes through but it applies to a different level of the supply chain.

3.7.4 Demand function

Consumer demand is supposed to be fully inelastic. This assumption is made for the sake of tractability and turns out to be innocuous for our purposes. It can certainly be the case that the demand function is not perfectly rigid but is negatively sloped. This makes upward price deviations less attractive since the demand is reduced, while downward deviations become more appealing. With a negatively sloped demand function $d(\cdot)$, we have $d(c_1) > d(\delta c_2)$ for $\delta > \frac{c_1}{c_2}$. If the storage capacity of each retailer is $d(c_1)$, it follows that when both firms purchase $d(c_1)$ in the first period in order to sell it profitably in the two periods some quantity will remain unsold. Clearly, this cannot be an equilibrium and the firms will have an incentive to undercut below δc_2 . It is well known in the literature that in this setting a mixed strategy equilibrium exists. The incentive to increase prices immediately with a positive shock should persist, even though it is softer.

3.8 Concluding remarks

In this chapter we provide a theoretical explanation for the well-established phenomenon of asymmetric price adjustments to input cost shocks. Using a model of dynamic price competition, we show that the presence of profitable storing allows competitive firms to credibly commit to immediately increase their prices above current marginal costs when they anticipate higher input costs. As a result, competition is mitigated and firms earn positive profits. If input costs are expected to decline, the price adjustment is slower and prices reflect current marginal costs, which entails zero profits. Our study suggests that empirical models should also consider the impact of anticipated cost changes when estimating price patterns over time. This can be done via an investigation of the firms' price decisions before a cost change materializes.

Even though our results are shown in a Bertrand-Edgeworth framework, profitable storing remains the driving force for asymmetric pricing in alternative standard market structures such as monopoly or Cournot competition. Our findings apply to the gasoline market as well as to other important sectors characterized by storage opportunities. For instance, banks that issue deposits and employ the funds to provide loans generally adjust the amount of liquidity they possess and the rates on their loans in response to the announcement of a change in the central bank's interest rate.

Our analysis is potentially significant in different aspects. We develop a model that focuses on the supply side and derives the pattern of asymmetric pricing as a unique prediction of the game, abstracting from market imperfections such as collusion among firms or limited information of consumers. Our results recommend an empirical investigation that disentangles the well-known demand side effects from the supply side effects identified in our analysis.

3.9 Appendix

This Appendix collects the proofs.

Proof of Lemma 7. In the quantity setting game, the analysis proceeds through the following cases:

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- (i) $p_{2i} = p_{2j} > c_2 \Rightarrow q_{2i}^m = \frac{d}{2}, i = 1, 2$.
- (ii) $p_{2i} = p_{2j} = c_2 \Rightarrow \sum_{i=1}^2 q_{2i}^m \leq d$.
- (iii) $p_{2i} > p_{2j} > c_2 \Rightarrow q_{2i}^m = 0; q_{2j}^m = d$.
- (iv) $p_{2i} > p_{2j} = c_2 \Rightarrow q_{2i}^m = d - q_{2j}^m; q_{2j}^m \in [q_{1j}^r, d]$.
- (v) $p_{2i} > c_2 > p_{2j} \Rightarrow q_{2i}^m = d - q_{2j}^m; q_{2j}^m = q_{1j}^r$.
- (vi) $p_{2i} = c_2 > p_{2j} \Rightarrow q_{2i}^m \in [\min q_{1i}^r, d - q_{2j}^m, d - q_{2j}^m]; q_{2j}^m = q_{1j}^r$.
- (vii) $p_{2i} = p_{2j} < c_2 \Rightarrow q_{2i}^m = \min q_{1i}^r, \max \frac{d}{2}, d - q_{2j}^m, i = 1, 2$.
- (viii) $p_{2j} < p_{2i} < c_2 \Rightarrow q_{2i}^m = \min q_{1i}^r, d - q_{2j}^m; q_{2j}^m = q_{1j}^r$.

A. Suppose $\sum_{i=1}^2 q_{1i}^r \leq d$. The candidate equilibria in the price setting game are (a) $p_{2i} = p_{2j} = c_2$; (b) $p_{2i} = p_{2j} > c_2$; (c) $p_{2i} > p_{2j} \geq c_2$; (d) $p_{2i} \geq c_2 > p_{2j}$; (e) $p_{2i} < c_2, i = 1, 2$.

We first show that candidate (a) is an equilibrium. It follows from (ii) that the equilibrium in the quantity setting game is $q_{2i}^m \in [q_{1i}^r, d]$, which yields profits for firm i equal to $\pi_{2i} = c_2 q_{1i}^r$.¹⁷ Given (iv), when $q_{2j}^m = d$ we can see that no profitable upward price deviation exists. From (vi) it follows that there is no incentive to deviate downward either. Therefore, the candidate (a) is an equilibrium, which implies $p_{2i}^* = c_2, \sum_{i=1}^2 q_{1i}^{m*} \leq d$ and $q_{2i}^{r*} = 0, i = 1, 2$.

We now show that the price equilibrium (a) is unique. Candidate (b) is not an equilibrium since if firm i sets a price $p_{2j} - \epsilon > c_2$, where $\epsilon > 0$ and infinitely small, it can get higher profits. Candidate (c) is not an equilibrium since firm j can set $p_{2j}' \in (p_{2j}, p_{2i})$ and get higher profits. Candidate (d) is not an equilibrium since firm j can set a price $p_{2j}' \in (p_{2j}, c_2)$ and gain by selling its reserves. If it does not have any reserve, firm i can gain by setting a higher price. Candidate (e) is not an equilibrium since both firms have an incentive to raise their prices. Therefore, the outcome $(p_{2i}^*, q_{2i}^{m*}, q_{2i}^{r*})$ is an equilibrium in the second period continuation game if and only if $p_{2i}^* = c_2, \sum_{i=1}^2 q_{1i}^{m*} \leq d$ and $q_{2i}^{r*} = 0, i = 1, 2$.

B. Suppose $\sum_{i=1}^2 q_{1i}^r > d$. Since the second period is the final period of the game, each firm wants to exhaust its reserves. In equilibrium the market clears (the two firms in aggregate fully cover the market) and a firm's reserve is the residual

¹⁷Indeed, there are other equilibria in the quantity setting game when firm i carries less than $\frac{d}{2}$ from the first period and firm j carries more than $\frac{d}{2}$. In these equilibria, firm i buys some quantity at c_2 and serves up to half the market, while firm j cannot sell all its reserves. However, this cannot support a SPNE in the second period continuation game, since firm i has an incentive to undercut in order to sell all its reserves.

from the first period that the firm is unable to sell in the second period, namely, $\sum_{i=1}^2 q_{2i}^{m*} = d$ and $q_{2i}^{r*} = \max 0, q_{1i}^{r*} - q_{2i}^{m*}$, $i = 1, 2$. Since the firms do not order any additional quantities, this game corresponds to a price competition game with (a)symmetric capacity constraints. We know from Levitan and Shubik (1972) and Osborne and Pitchik (1986) that there exists an equilibrium (which is generally unique), where firms randomize in prices within the support $[p_2^*, \bar{p}_2^*] \subseteq [0, c_2]$. Any price above c_2 cannot be chosen with positive probability, since price undercutting is always profitable. Moreover, choosing with probability 1 a price equal to c_2 cannot be sustained as an equilibrium since each firm has an incentive to undercut the rival and sell off all its reserves. ■

Proof of Remark 2. We know from Lemma 7 that $p_{2i}^* \leq c$. For $\delta < 1$ no firm has an incentive to store some quantity for the next period, i.e., $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$. Therefore, as in Chowdhury (2005), we have $p_{\tau i}^* = c$ and $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$, $\tau, i = 1, 2$, in equilibrium. For $\delta = 1$, storing is not harmful if $\sum_{i=1}^2 q_{1i}^r \leq d$. Therefore, any outcome $\sum_{i=1}^2 q_{1i}^r \leq d$ such that $p_{\tau i}^* = c$ and $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$, $\tau, i = 1, 2$, can be sustained in equilibrium. ■

Proof of Proposition 5. A. For $\delta \geq \frac{c_1}{c_2}$ each firm finds it profitable to order one unit today at c_1 and sell it tomorrow if the price in the second period is c_2 . First, we argue that no equilibrium exists which involves a price $c_1 < p_{1i} < \delta c_2$, $i = 1, 2$. Assume that there exists an equilibrium in the quantity setting game which supports these prices as an equilibrium strategy. Such an equilibrium must imply that each firm will order d in the first period, i.e., $q_{1i} = d$, $i = 1, 2$, since for any given quantity of the rival a firm can sell profitably in either period. Note that the outcome $q_{1i}^m = 0$, $q_{2i}^m = d$ with $q_{1j}^m = d$, $q_{2j}^m = 0$ (and the reverse) cannot be supported as an equilibrium in quantities for $c_1 \leq p_{1i} < \delta c_2$, $i = 1, 2$. The rationale is the following. Suppose that firm j deviates in the first period and stores a quantity $\tilde{q}_{1j} > 0$ for the next period. It follows from the proof of Lemma 7B that a (unique) mixed strategy equilibrium in the second period continuation game exists. Firm j can always choose a sufficiently small quantity $\tilde{q}_{1j} > 0$ such that the lower bound of the price interval is higher than p_{1j}/δ . This implies that firm j which stores \tilde{q}_{1j} for the next period gains from such a deviation. This result is crucial in order to show that there exists an incentive for upward deviation in prices in the first period. Let $L_i \equiv \pi_i : \pi_i = (p_{1i} - c_1)q_{1i}^m + (\delta p_{2i} - c_1)q_{2i}^m$ be the

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set of firm i 's profits associated with the candidate $c_1 \leq p_{1i} < \delta c_2$, $i = 1, 2$, if an equilibrium in quantities exists. From the previous discussion and the result in Lemma 7B it follows that $\sup(L_i) < (\delta c_2 - c_1)d$. Now, we characterize the equilibrium in the quantity setting game in the first period following a deviation such that $p'_{1i} > \delta c_2 > p_{1j}$. Let $S_i \equiv \{\pi'_i : \pi'_i = (p'_{1i} - c_1)q_{1i}^{m'} + (\delta p'_{2i} - c_1)q_{2i}^{m'}\}$ be the set of firm i 's profits associated with $p'_{1i} > \delta c_2 > p_{1j}$. Since firm i has a strict preference for selling today while firm j has a strict preference for selling tomorrow, firm i never wants to engage in a price war in the second period, which implies that d will be sold in both periods and $p'_{2i} = c_2$. Moreover, following the previous argument, firm j will always prefer to bring a positive quantity to the second period, which implies that firm i can sell something in the first period. Therefore, $\inf(S_i) > (\delta c_2 - c_1)d > \sup(L_i)$. Since an equilibrium in quantities with $p'_{1i} > \delta c_2 > p_{1j}$ exists (e.g., $q_{1i}^m = d$, $q_{2i}^m = 0$ and $q_{1j}^m = 0$, $q_{2j}^m = d$), it follows that firm i has an incentive to deviate and $c_1 \leq p_{1i} < \delta c_2$, $i = 1, 2$, cannot be an equilibrium.

It can immediately be shown that $p_{1i} > \delta c_2 > p_{1j}$ cannot be an equilibrium, since firm j can always set a price $p'_{1j} = p_{1i} - \epsilon > \delta c_2$, where $\epsilon > 0$ and infinitely small, and gain. Moreover, $p_{1i} = \delta c_2 > p_{1j}$ cannot be an equilibrium, either. Firm j does not have any incentive to deviate only when $q_{1j}^m = 0$ and $q_{2j}^m = d$ in equilibrium. However, in this case firm i gets profits $(\delta c_2 - c_1)d$ and we know from the previous discussion that it can set $p'_{1i} > \delta c_2 > p_{1j}$ and gain. It is also straightforward to argue that an equilibrium which involves $p_{1i} \geq \delta c_2$, $i = 1, 2$, where at least one firm sets $p_{1i} > \delta c_2$ cannot be sustained as the standard undercutting reasoning applies.

The only price candidate that we have not investigated yet is $p_{1i} = \delta c_2$, $i = 1, 2$. Note that, irrespective of the direction of price deviation by firm i , there exists an equilibrium in the quantity setting game where $q_{1i}^m = 0$, $q_{2i}^m = d$ and $q_{1j}^m = d$, $q_{2j}^m = 0$. In this case, no deviation is profitable. A similar argument applies for any price deviation by firm j . Then, an outcome is a SPNE if and only if $p_{1i}^* = \delta p_{2i}^* = \delta c_2$, $\sum_{i=1}^2 q_{\tau i}^{m*} = d$, $q_{1i}^{r*} = d - q_{1i}^{m*}$ and $q_{2i}^{r*} = 0$, $\tau, i = 1, 2$.

B. For $\delta < \frac{c_1}{c_2}$, storing is never profitable, i.e., $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$. Therefore, the standard Bertrand rationale applies and an outcome is a SPNE if and only if $p_{\tau i}^* = c_\tau$, $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$ and $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$. ■

Proof of Proposition 6. Since storing is not profitable, the same argument as in the proof of Proposition 5B applies. ■

Proof of Proposition 7. Let $\delta \geq \frac{c_1}{c_2}$. We first derive the equilibrium in the first period quantity setting game when prices are $p_{1i} = \delta p_{2i} = \delta c_2$, $i = 1, 2$. Note that in equilibrium both firms will order $\sum_{i=1}^2 q_{1i} \geq d$, since the marginal (and average) cost in (3.4) is $\tilde{c}_1 = c_1$ for $\sum_{i=1}^2 q_{1i} \leq d$. The quantity ordered by firm i in the first period can be written as $q_{1i} = \tilde{q}_{1i}^e + q_{1i}^e$, where \tilde{q}_{1i}^e denotes the quantity ordered by firm i such that together with the corresponding quantity ordered by firm j it holds $\sum_{i=1}^2 \tilde{q}_{1i}^e = d$. For a given \tilde{q}_{1i}^e , $i = 1, 2$, firm i chooses q_{1i}^e and faces an average cost equal to $\tilde{c}_1 = \frac{c_1 d + c_2 \sum_{i=1}^2 q_{1i}^e}{d + \sum_{i=1}^2 q_{1i}^e}$. Firm i 's maximization problem is

$$\max_{q_{1i}^e \geq 0} \delta c_2 (\tilde{q}_{1i}^e + q_{1i}^e) - \tilde{c}_1 (\tilde{q}_{1i}^e + q_{1i}^e),$$

which yields the following first-order condition for an interior solution

$$\frac{\delta c_2 (d + \sum_{i=1}^2 q_{1i}^e)^2 - c_1 d (d + q_{1j}^e - \tilde{q}_{1i}^e) - c_2 \left[(\sum_{i=1}^2 q_{1i}^e)^2 + d (2q_{1i}^e + q_{1j}^e + \tilde{q}_{1i}^e) \right]}{(d + \sum_{i=1}^2 q_{1i}^e)^2} = 0.$$

Combining terms implies

$$q_{1i}^e (q_{1j}^e) = - (d + q_{1j}^e) + \frac{(c_2 - c_1)^{\frac{1}{2}} [c_2 d (d + q_{1j}^e - \tilde{q}_{1i}^e) (1 - \delta)]^{\frac{1}{2}}}{c_2 (1 - \delta)}. \quad (\text{A.1})$$

Equation (A.1) gives the best response function for firm i . In the same vein, we obtain the best response function for firm j

$$q_{1j}^e (q_{1i}^e) = - (d + q_{1i}^e) + \frac{(c_2 - c_1)^{\frac{1}{2}} [c_2 d (d + q_{1i}^e - \tilde{q}_{1j}^e) (1 - \delta)]^{\frac{1}{2}}}{c_2 (1 - \delta)}. \quad (\text{A.2})$$

Solving (A.1) and (A.2) simultaneously implies that in the unique symmetric equilibrium the quantity ordered by firm i in the first period is

$$q_{1i}^* = \tilde{q}_{1i}^{e*} + q_{1i}^{e*} = \frac{(c_2 - c_1)d}{4c_2(1 - \delta)}, \quad i = 1, 2. \quad (\text{A.3})$$

Since $\sum_{i=1}^2 \tilde{q}_{1i}^e = d$, (A.3) is a solution for firm i 's maximization problem if $\frac{(c_2 - c_1)d}{4c_2(1 - \delta)} - \frac{d}{2} \geq 0$, which implies $\delta \geq \frac{1}{2}(1 + \frac{c_1}{c_2})$. Firm i 's profits are given by $\pi_i^* = (\delta c_2 -$

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$\frac{c_1 d + c_2 \sum_{i=1}^2 q_{1i}^{e*}}{d + \sum_{i=1}^2 q_{1i}^{e*}} q_{1i}^* = \frac{(c_2 - c_1)d}{4} > 0$. In the sequel, we split the analysis according the value of the discount factor δ .

A. Assume $\delta \geq \frac{1}{4}(3 + \frac{c_1}{c_2})$. For $\delta = \frac{1}{4}(3 + \frac{c_1}{c_2})$ we obtain from (A.3) $q_{1i}^* = d$, $i = 1, 2$. Since $\frac{\partial q_{1i}^*}{\partial \delta} > 0$, it follows that $q_{1i}^* = d$, $i = 1, 2$, still holds for higher values of δ . In words, in the first period each firm orders its full capacity. Therefore, the analysis of Proposition 5 carries over and $p_{1i}^* = \delta p_{2i}^* = \delta c_2$ are the equilibrium prices.

B. Assume $\frac{c_1}{c_2} \leq \delta < \frac{1}{4}(3 + \frac{c_1}{c_2})$. We first demonstrate that the candidate $p_{1i} = \delta p_{2i} = \delta c_2$, $i = 1, 2$, cannot be an equilibrium since a firm has an incentive to (infinitely) increase its price in the first period. Such a deviation would not be profitable if and only if the rival orders and sells d in the first period. We show that this cannot be an equilibrium in the quantity setting game (if it exists at all). Note that, since firm i 's (marginal) revenue following the deviation is higher (or at least not lower), firm i does not want to buy less than in the candidate equilibrium and, in response, the non-deviating firm j does not want to buy more. For $\delta \geq \frac{1}{2}(1 + \frac{c_1}{c_2})$, the equilibrium in the quantity setting game with $p_{1i}^* = \delta p_{2i}^* = \delta c_2$ is still described by (A.3). Therefore, following an upward price deviation of firm i , the non-deviating firm j will not buy more than $\frac{(c_2 - c_1)d}{4c_2(1 - \delta)} < d$. For $\delta < \frac{1}{2}(1 + \frac{c_1}{c_2})$, the solution in (A.3) is no longer valid. This implies that firm i 's maximization problem yields $q_{1i}^e = 0$. In words, for prices $p_{1i} = \delta p_{2i} = \delta c_2$, $i = 1, 2$, the firms do not want to order in aggregate more than d . For our purposes, it is sufficient to show that an equilibrium in the quantity setting game with $p_{1i} = \delta p_{2i} = \delta c_2$, $i = 1, 2$, cannot involve $q_{1i} = 0$ and $q_{1j} = d$. This is because, given that firm j buys d in the first period, firm i 's marginal revenue is higher than the marginal cost at zero, i.e., $\delta c_2 \geq c_1$, and therefore firm i has an incentive to order some quantity in the first period (and sell it in either period). This implies that the non-deviating firm j will buy less than d . As a consequence, for $\frac{c_1}{c_2} \leq \delta < \frac{1}{4}(3 + \frac{c_1}{c_2})$, firm i can set an infinitely high price to cover the residual demand in the first period and be better off.

As long as the first period prices are higher than δc_2 , each firm has an incentive to undercut to sell in the first period. Moreover, any price below δc_2 cannot be supported as an equilibrium, since the non-deviating firm will always prefer to sell at least some positive quantity in the next period while the rival could increase the

price and sell profitably in the first period. Along the same lines, it can be shown that an asymmetric price configuration (one firm sets the price above δc_2 and the rival below δc_2) also cannot be an equilibrium. Hence, for $\frac{c_1}{c_2} \leq \delta < \frac{1}{4}(3 + \frac{c_1}{c_2})$, there is no equilibrium in the price setting game and no SPNE exists in pure strategies. Since the rigid demand allows a deviating firm to set an infinite price, no SPNE exists even in mixed strategies.

C. Assume $\delta < \frac{c_1}{c_2}$. The proof of Proposition 5B is replicated. ■

Proof of Proposition 8. First note that $q_{1i}^r > 0$ is never optimal since $\tilde{c}_1 > c_2 \geq p_{2i}$ (from Lemma 7). It is straightforward to show that any price configuration where $p_{1i} > p_{1j} \geq c_1$, $p_{1i} > c_1 > p_{1j}$ or $p_{1i} = p_{1j} > c_1$ cannot be sustained as an equilibrium since the standard undercutting rationale applies.

To proceed, it is useful to determine the outcome in the first period quantity setting game for some relevant cases:

(i) $p_{1i} > p_{1j} = c_1 \Rightarrow q_{1i}^m = 0$; $q_{1j}^m = d$. Any $q_{1i}^m > 0$ cannot be an equilibrium, since firm j 's best response would be $q_{1j}^m = d$ (which guarantees positive profits since $c_1 > \tilde{c}_1$), and firm i would make losses.

(ii) $p_{1i} > c_1 > p_{1j} \geq \frac{c_1 + c_2}{2}$. There does not exist any pure strategy Nash equilibrium. The reason is that there is a critical threshold $\tilde{q}_{1i} \in (0, d]$ at which $\pi_j = (p_{1j} - \tilde{c}_1)d = 0$ and $\pi_j > 0$ if and only if $q_{1i} > \tilde{q}_{1i}$. Hence, the best response function of firm j is discontinuous and jumps from $q_{1j}(q_{1i}) = 0$ for $q_{1i} < \tilde{q}_{1i}$ to $q_{1j}(q_{1i}) = d$ for $q_{1i} \geq \tilde{q}_{1i}$. For our aims, it is sufficient to show that in any mixed strategy Nash equilibrium we must have that (a) the (expected) profit of firm i is strictly positive for $p_{1i} > c_1$, and (b) the (expected) profit of firm j is zero. Afterwards, we demonstrate that such an equilibrium exists. The result (a) follows since there exists a quantity $q_{1i} < \tilde{q}_{1i}$ such that $\pi_i = (p_{1i} - \tilde{c}_1)q_{1i} > 0$ for $p_{1i} > c_1 \geq \tilde{c}_1$ and $\pi_j = (p_{1j} - \tilde{c}_1)d < 0$. To see the result (b), recall that any strategy $q_{1j} \in (0, d)$ is strictly dominated by the two extreme values 0 and d . The only strategy profile which is part of a mixed strategy Nash equilibrium is the set $0, d$. Since any pure strategy which is part of a mixed strategy Nash equilibrium must yield the same (expected) payoff and $q_{1j} = 0$ gives zero payoff, then $q_{1j} = d$ must also give zero, which implies that the profit of firm j is zero. A mixed strategy Nash equilibrium in this subgame prescribes that firm i chooses with probability 1 the quantity \tilde{q}_{1i} and firm j randomizes between zero and d such

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that its expected quantity equals $d - \tilde{q}_{1i}$.

(iii) $p_{1i} = c_1 > p_{1j} \geq \frac{c_1 + c_2}{2}$. The equilibrium described in (ii) still holds true, yet in addition we have an equilibrium in pure strategies where $q_{1i} = 0$, $i = 1, 2$.

(iv) $p_{1i} < c_1 \Rightarrow q_{1i}^m = 0$, $i = 1, 2$. Each firm has a dominant strategy not to serve the market.

Combining (ii) and (iv) it is easy to argue that any $c_1 > p_{1i} \geq p_{1j}$ or $p_{1i} = c_1 > p_{1j}$ cannot be an equilibrium since firm i has an incentive to increase the price above c_1 and gain.

It remains to be shown that $p_{1i} = c_1$, $i = 1, 2$, is chosen in equilibrium. From (iii) it follows that firm i does not have an incentive to deviate downwards. Similarly, if firm i deviates upwards, we are in the quantity equilibrium described in (i) so that firm i does not gain from deviation. Hence, any outcome $(p_{\tau i}^*, q_{\tau i}^{m*}, q_{\tau i}^{r*})$, where $p_{\tau i}^* = c_\tau$, $\sum_{i=1}^2 q_{\tau i}^{m*} \leq d$ and $q_{\tau i}^{r*} = 0$, $\tau, i = 1, 2$, sustains a SPNE. ■

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